Digitising the Inter-War Land Use Survey of Great Britain: A Pilot Project

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Executive Summary

- **During the 1930s, the Land-Utilisation Survey of Great Britain, directed by Professor L. Dudley Stamp, created a detailed record of the major land uses in England, Wales and southern Scotland**. They published this information on a set of 169 map sheets, using Ordnance Survey 1" maps as a base, and displaying land uses via a colour overlay:

- The Ordnance Survey's copyright in the 1920s base maps has long expired but copyright in the land use data belonged to Stamp and lasts for 70 years from his death in 1966. **Stamp's copyright passed to his assistant … who has given us verbal permission for the maps to be used in a not-for-profit project providing public access to the data.**
- A digitisation project needs good quality paper copies of the maps, creating a better quality set of scans for dissemination as well as giving better results during the class extraction process. Some colour variation is unavoidable given the number of different printers used by the Survey, and the best approach is probably to combine sheets from different sources.
- **Scanning, geo-referencing, archiving and Internet dissemination are all feasible, despite the lack of a printed grid and coordinate system on the maps.** The lack of printed coordinates is best dealt with by superimposing scans of a series of digital maps which are already geo-referenced. We recommend that the maps used for this be over fifty years old and so out of OS copyright, to avoid imposing any new copyright restrictions.
- Geo-referencing the LUS maps enables them to be overlaid on modern products such as the CEH Land Cover Maps. However, the paper maps will have experienced some distortion so geo-referencing must include additional points within the sheets, not just the corners.
- A full project would benefit from various offers of assistance which depend on the project being non-commercial and the scanned maps being made freely available. However, this free availability need not include the digital vector mapping.
- **The trials described in this report clearly show that it is possible to produce a good quality digital vector map from the paper maps of the First Land Utilisation Survey.** A purely manual method was very accurate but took ten times as long as automated methods. We recommend method 2, 'supervised classification', as it was quicker than method 1, 'post classification' and produced equivalent results.
- It was not possible, using the automatic classification methods described in this study (trials 1 and 2), to extract land-use classes indicated by shading and symbols in the original base map. In these cases, only the major classes can be identified.
- Significant differences exist between Stamp's categories and those in modern digital imagery. For example, Stamp's 'Heath and Moorland' includes rough grass which is a different class in LCM2000.

Introduction

This report investigates computerising the maps created by on-the-ground land use surveys of Britain to create a reference baseline for environmental modelling. This reference dataset could be used to develop tools for catchment characterisation under the Water Framework Directive, and for forecasting environmental effects of agriculture and land-use change

The first part of the report covers the available data. Its main concern is the 1930s Land Utilisation Survey of Britain directed by Professor L. Dudley Stamp (later Sir Dudley) of the London School of Economics (hereafter called simply the ‘Stamp Survey’), but it more briefly covers the Second Land Utilisation Survey of the 1960s, directed by Alice Coleman of King’s College London (the ‘Second Survey’). We outline how the surveys were carried out, and then provide more detailed information on what materials now exist and who owns copyright in them.

The remainder of the report describes methods for computerising the Land Use Survey’s maps. It begins by describing methods for creating, geo-referencing and making available on-line simple digital images of the maps. It goes on to discuss three alternative methodologies for extracting systematic land-use data from the digital images, for further analysis and comparison with modern data. This includes estimates of the time, and therefore the cost, required for a project working with the full set of maps for England and Wales.

1: The Land Use Surveys

There has recently been some interest in the place of land-use mapping within the intellectual history of British geography (Rycroft and Cosgrove, 1995; Rycroft and Cosgrove, 1999). However, our own main concern is the actual data created by the surveys: the field survey data, various compilations from them and the published maps. Although our initial assumption was that these materials and copyright in them would be held by institutions, it became clear that much belonged to individuals involved in the projects, and significant materials are currently in private houses. Contact details are included in Appendix A.

1.1 The Stamp Survey

This outline history of the Land Utilisation Survey is largely based on the account in the first chapter of Stamp’s *The Land of Britain, Its Use and Misuse* (1948, and later editions). The origins of the Survey lay in earlier work supported by the Geographical Association, but these were all on a very local scale. Following earlier work in Burma, Stamp joined the London School of Economics in 1926, and in 1929 began to plan a national land use survey to be carried out primarily through local schools. In 1930, he obtained a grant (£500) from the Rockerfeller Foundation for a pilot project covering Surrey. He obtained support from local education authorities and particular government departments and agencies, such as the Ministry of Agriculture and the Forestry Commission, but this was not an official survey.

Work was organised by administrative county, the first contact usually being with the Director of Education. Arrangements were in place for most English counties by the summer of 1931, and for most Welsh and Scottish counties a year later. The first of the resulting 1” maps was published in January 1933. By the autumn of 1934, 90% of the field survey maps had been returned, but two problems were emerging. Firstly, it proved impossible to find local volunteers for many areas and the Survey had had to organise university students and its own staff to fill the gaps; the very last area to be surveyed was part of the Isle of Arran in September 1941, all other areas being completed before the outbreak of war. The second and more serious problems was funding the publication of the maps: disagreements with the Ordnance Survey over the cost of printing a single sheet, and with Durham County Council over a verbal order for maps, led to the Survey becoming insolvent in September 1934. New funding was obtained from the Pilgrim Trust, but one of the project's staff had to fund publication of a map she had worked on herself, and in June 1936 Stamp signed an agreement with the LSE in which he took on 'complete personal responsibility for the finances and conduct of the survey' (1948, p.12).

The practical consequence of this tortured history was an extremely delayed and complex publishing programme. The first nineteen sheets were printed for Stamp by the Ordnance Survey, but early in 1935 the OS complained that printing the land use maps was straining their resources. From then on, the OS supplied the 'base plates' (black, contours and water) for printing, and took a royalty of £1 per 100 maps sold. Between 1935 and 1949, the remaining sheets were produced by eight separate printers. Between 1935 and 1942, most maps were printed by G.W. Bacon & Co., and when the LSE was evacuated at the outbreak of war this firm provided the Survey with temporary office space. However, in May 1942 their works was completely destroyed in a German raid and the Survey lost all its office records, its main stock of printed maps and nearly all printing plates. Thereafter, printing work was shared between Stanford's and W. & A.K. Johnston. Obviously, this history means that the available maps may vary, especially in their colours, not only because of differing amounts of wear and tear but because of variations in printing methods, paper and inks.

The Second World War did, however, bring greater official support for the Survey. The emergency County Agricultural Committees were loaned the six-inch field sheets, and an annual Treasury grant of £1,500 funded publication of the remaining maps. In 1942, Stamp was appointed Chief Adviser to the Ministry of Agriculture on rural land utilisation, and in practice the Survey and some of its staff were absorbed into the Ministry's new planning branch. In 1943, the Scottish Departments of Health and of Agriculture funded publication of twenty-one maps covering the more populous parts of Scotland. Government funding ended in late 1945. The remaining sheets for England and Wales all appeared in 1946. Further sheets for Scotland appeared between 1947 and 1949, but sheets covering northern Scotland were compiled and placed in the Royal Geographical Society collection, but never published.

In all, the Land Utilisation Survey published 135 maps of England and Wales, an additional 34 of Scotland, and 92 County Reports (see below). The total cost of the survey was £52,918, of which £33,729 was printing costs; Stamp noted that the cost would have been far greater had staff been paid at market rates. The survey's total income was £40,716, of which £3,000 came from the Pilgrim Trust, £4,242 from the Rockerfeller Foundation, £11,000 from the Treasury during the war, and £18,855 from sales. How the net loss of £12,201 was absorbed is unclear, although the LSE wrote off all losses up to June 1936.

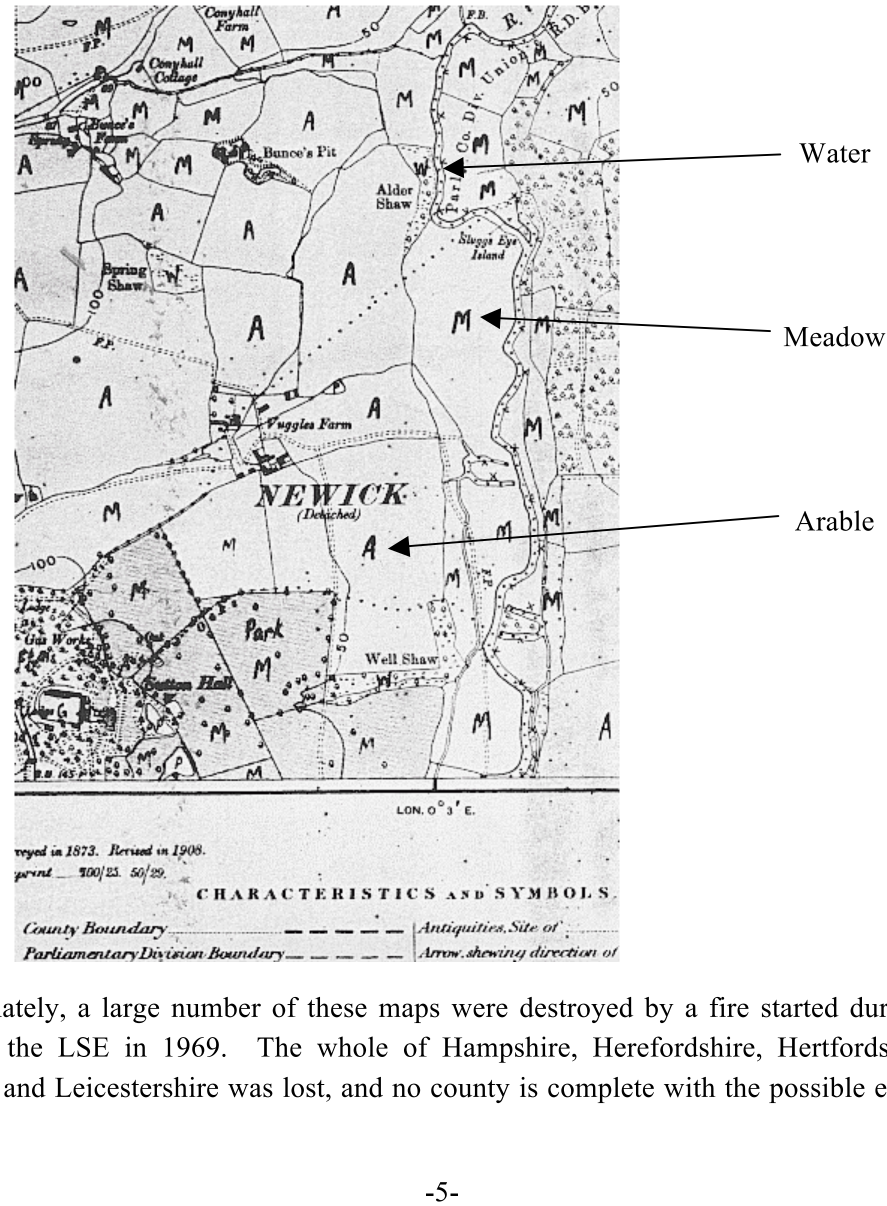
Northern Ireland: Although Stamp's Land Utilisation Survey was limited to Great Britain, a separate survey of Northern Ireland was carried out in 1937-9, organised by the Geographical Association (N. Ireland) with Douglas Hill as honorary Director. This published a set of eleven sheets at 1:63,360 scale in 1947-51, using an OS 1" *Popular Edition* base map.

1.2 Surviving Materials

These are described in order of creation:

Field survey maps: A substantial fraction of the original field maps, as sent back by the schools participating in the survey, are still held by the London School of Economics. They were originally stored in the Geography department, but were moved to the main library in 1979; in May 2003 they occupied about 60 map cabinet drawers in a closed area of the library basement, made particularly inaccessible by nearby building work. These sheets are OS six inch to the mile maps; one example came from an edition published 1919-20, another was originally published in 1902. The Survey rubber stamped each sheet to create a small form on which the name of the surveyor, the month and year of the survey but not, usually, the institution. The majority of surveyors recorded land-use by simply adding letter codes, as in figure 1, and their sheets therefore contain no information that does not appear in more easily used form on the published LUS maps. However, about 40% of the sheets were also coloured by the surveyor, and some include additional marginal notes, so providing more detailed land use information which does not appear on the published maps. Note that for some counties, the LSE held only Photostats, the originals being returned to the relevant education authority.

Figure 1: Sample Field Survey map from the Stamp Survey



Unfortunately, a large number of these maps were destroyed by a fire started during student protests at the LSE in 1969. The whole of Hampshire, Herefordshire, Hertfordshire, Kent, Lancashire and Leicestershire was lost, and no county is complete with the possible exception of

Rutland. Other sheets may have been 'borrowed' by LSE staff, and some sheets requisitioned by County Agricultural Committees during WW II may not have been returned. Black and white microfilms of all surviving sheets were made immediately after the 1969 fire but these seem to have been lost (Chris Board, formerly of the LSE, is pursuing this issue).

Colour separations: Samples of the colour separations used in printing the Stamp maps were preserved by Christie Willatts, Stamp's deputy, who died relatively recently. These are now held at his home by Dr. Board, who is willing to be contacted about them. The technical methods described later in this report are essentially about extracting colour layers from the base maps, i.e. reconstructing the colour separations, so if *all* the separations had survived analysis would have been drastically simplified. Samples may be relevant to calibrating techniques.

Published 'One Inch' maps: The principal output from the Stamp Survey was, as already discussed, a set of 169 1" maps, over-printing land use information onto reproductions of the Ordnance Survey's *Popular Edition* maps. The remainder of this report contains several samples from these sheets, while a detailed study of the base maps is provided by Hodson (1999). The individual sheets are listed in Appendix B.

Published 'Ten Inch' maps: Summary sheets at ten miles to the inch or (very similar) 1:625,000 were prepared during the war by the Ministry of Town and Country Planning, under the direction of Christie Willatts, Stamp's deputy who had become their Research Maps Officer. Four distinct maps were published, each covering Great Britain in two sheets:

- Land Utilisation
- Land Classification
- Types of Farming
- Grasslands (of England and Wales) and Vegetation (of Scotland)

It would be highly desirable to include at least one of these pairs in the initial digitisation programme, to provide a high level overview in the suggested web access system. More information about 'ten mile' planning maps is given by Hellyer (1993). See also Oliver (1992) for an overview of published land use maps.

The Land of Britain: The Stamp Survey also published a national overview (i.e. Stamp, 1948) and a series of 92 reports each covering one of the Administrative Counties of England, Wales and Scotland in between 40 and 200 pages; unlike the published maps, coverage of Scotland is complete. These reports were available individually and as a set of nine bound regional volumes. Each describes the work of the Survey in the relevant county; its geology, relief, soils and climate; the distribution of each land use; and a detailed description of 'land use regions' within the county. They also report special investigations by the particular author, which generally include processes of historical change.

1.3 Copyright

Dudley Stamp was very clearly the principal author of the maps published by the Land Utilisation Survey, so under current law copyright on the maps will last for seventy years from his death on August 8th 1966, i.e. until 2036. The Ordnance Survey would have held an additional copyright in the maps when they were first published, but as Crown Copyright lasts for only fifty years from the date of publication this is no longer an issue.

Any project to digitise the Stamp maps clearly depends on the agreement of the copyright holder. The maps themselves do not include a copyright notice, but they were in fact published by Geographical Publications Ltd, a company established for the purpose in which Stamp himself was the principal shareholder (the company's role is clearer in the books published by the Survey). Under Stamp's will, a copy of which is held by Will Pilfold of Sussex University, his shares passed to [a former member of LUSGB staff]. Geographical Publications was wound up in September 1993. However, Dr. Southall was able to speak to [the copyright holder] by telephone on May 12th 2003, and she confirmed that the copyright was transferred to her personally before the company was wound up.

In the same conversation, [the copyright holder] said she was happy for the maps to be used in a not-for-profit project which made them publicly accessible. This extremely generous offer needs to be confirmed in writing. She explained that she has arranged for the copyright to be inherited by her son, [who works in publishing]. Dr. Southall has also discussed the situation with him, on July 1st 2003, and he should clearly be involved in the drawing-up of a formal agreement.

1.4 Sourcing maps for scanning

As well as copyright, the proposed project obviously depends on obtaining copies of the paper maps to digitise. Further, as discussed below, our methods for extracting land use data from the scans depend on colour recognition and are sensitive both to changes in colour due to fading and to any markings on the sheets. The GBH GIS Project's experience is that even maps held by copyright libraries experience significant wear and tear. The best possible set of image scans of the LUS 1" sheets should probably be assembled via more than one route:

Purchase of second hand sheets: The project team and, independently, the Environment Agency were directed to David Archer as a very experienced dealer in Ordnance Survey maps. In March 2003, he was able to supply the Agency with 68 sheets for England and Wales, 22 of Scotland and 6 of N. Ireland, at prices varying between £10 and £12 per sheet. Of these 96 sheets, 85 (88%) were graded as in 'very nice condition', but the quality of some seemed problematic.

Purchase of unsold sheets: It has emerged that, in addition to its own collection, the LSE holds a substantial number of sheets returned by Edward Stanford, the map firm who had acted as the main agent for the Survey, and the LSE may be willing to sell copies. Unfortunately, continuing building work in their basement has made it impossible to clarify exactly what may be available.

Scanning of copies owned by map libraries: The Survey printed only 1,000 copies of each sheet, many were clearly lost in the war and the remainder are probably mostly held in libraries. It is therefore unlikely that we will be able to purchase a complete set of maps in truly excellent condition. However, it should be possible to scan other sheets held by libraries. This would obviously depend on the precise nature of the project and who it was being undertaken by. The Great Britain Historical GIS Project is well regarded by map librarians around Britain, and discussions show that they would be willing to assist provided the resulting scanned digital maps were made publicly available on-line, as with the current work of the Project. Copyright libraries are not willing to loan maps, but university map libraries also hold sets. We could obviously use maps held by Portsmouth, and another university has indicated it would be willing to scan its own maps for us, probably at a fairly notional cost.

1.5 The Second Land Use Survey

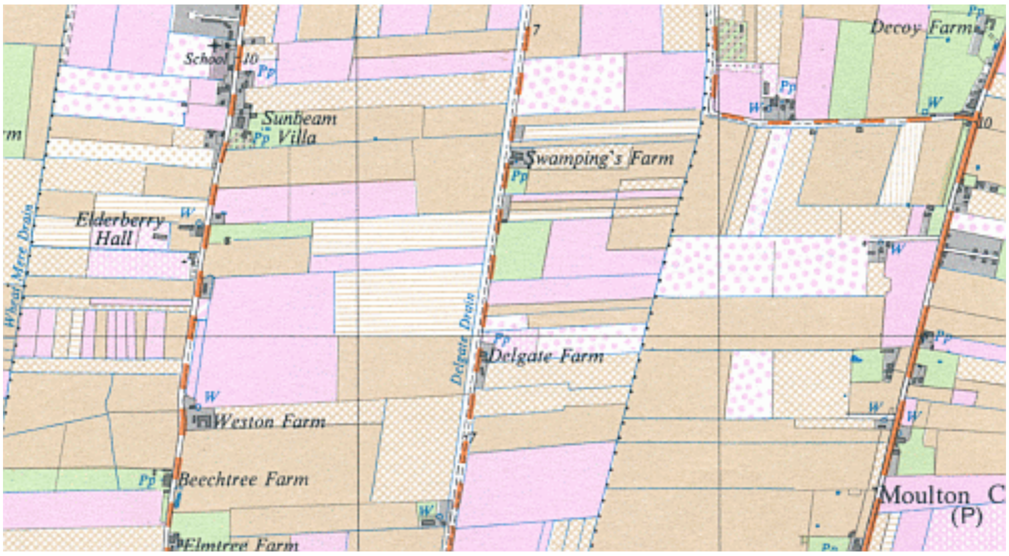
The Second Land Use Survey, directed by Professor Alice Coleman and again based in the Joint School of Geography of the LSE and King's College London, aimed to build on the experience of the first and employed a broadly similar geography, including the use of schools. In a number of respects, however, it was more ambitious: more detailed land use information was gathered, and they planned to publish the results at 1:25,000 rather than at one mile to the inch. The survey was launched in 1960 and survey work was half complete by 1963. Their survey of England and Wales was completed, but only 110 (15%) of the maps, each covering 200 km^2, were published. Two different printers were used.

Figure 2: Second Survey Colour Conventions

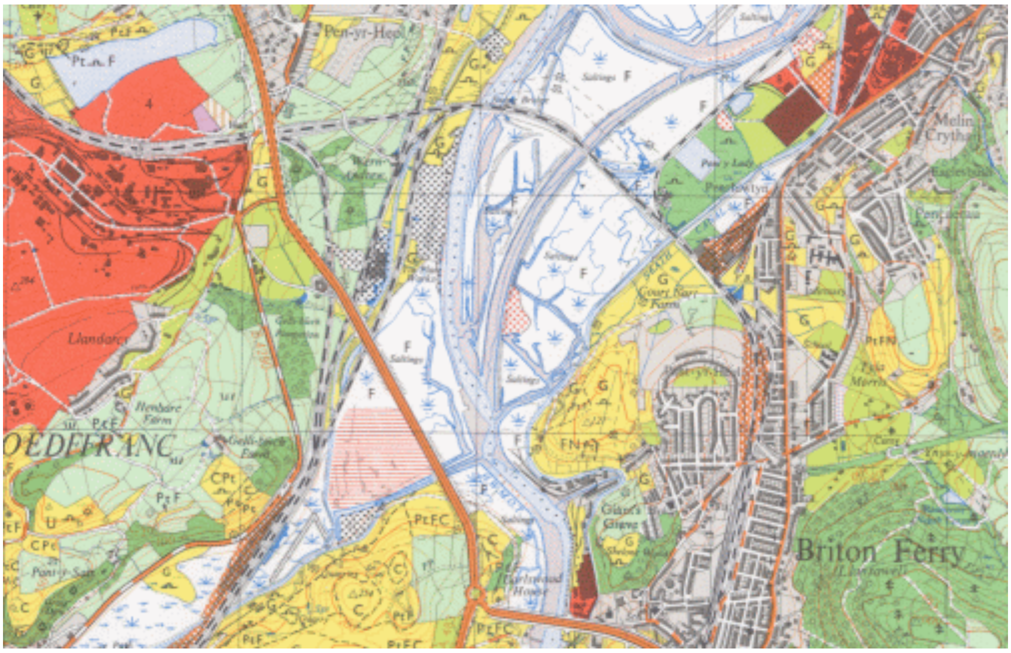
They recorded 70 different land uses. Figure 2, taken from Coleman and Shaw (1980, pp. 38-9) provides a key for 55 of them, printed using 11 colours. Rather than the Stamp Survey's classification of agricultural land primarily into just arable and pasture, they identified types of crop in some detail. Figure 3 below provides two contrasting samples from the published maps, and the greater detail compared to the Stamp survey is obvious. There are two reasons for suggesting that the work of the Second Survey is of interest despite the partial coverage:

Field Sheets: The original survey sheets exist for the whole country, at 1:10,000 scale, and were produced to a substantially higher standard than those of the Stamp Survey. They record 250 uses rather than 25 and, possibly crucially, the major uses were shown by colouring in areas rather than by pencil symbols; surveyors were required to use fifteen specific pencils from the 'Lakeland Derwent' range (Coleman & Shaw, 1980, p.11). There may therefore be some basis for automated extraction of data from the field sheets, although particular types of crop or farm animal are indicated by text, not colours.

Figure 3: Samples from Second Survey 1:25,000 sheets



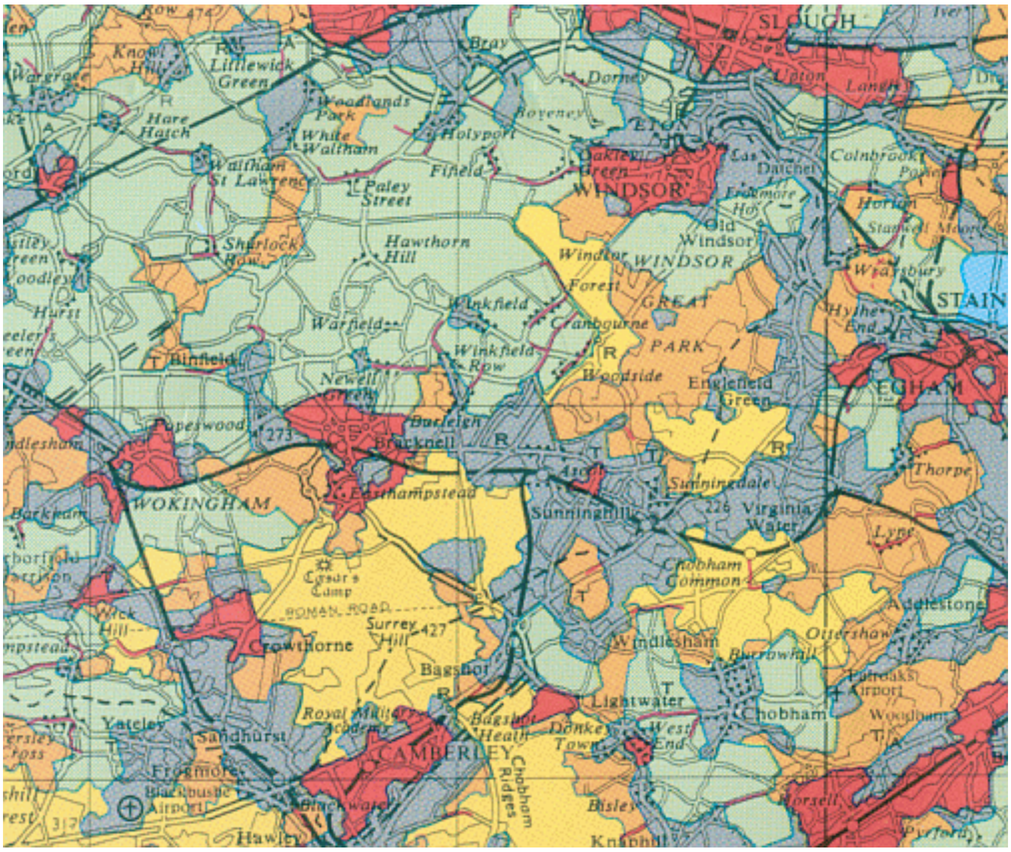
(a) Rural fenlands



(b) Briton Ferry, near Swansea

'Scapes and Fringes' maps: Although only a fraction of the 1:25,000 maps were published, the Second Survey **did** publish a map of the whole of England and Wales (Coleman *et al*, 1992). This map, at 1:400,000 scale, summarises land use as four 'scapes' and two 'fringes': *Townscape*, *Farmscape*, *Wildscape* and *Waterscape*, plus *Rurban Fringe* and *Marginal Fringe* (generally between Farmscape and Wildscape). Each 'scape' was a pattern of uses, not just an amalgamation of similar uses, and although classification was manual it followed very systematic principles, described in detail in the accompanying booklet. In particular, specific areas were included or generalised away using threshold sizes, and these were such that individual airfields are identifiable as 'Rurban Fringe' within farming areas. The result is arguably not dissimilar to the automated generalisation carried out in our own experiments with the Stamp Survey maps. Although the published 'Scapes and Fringes' map is at 1:400,000, the compilation sheets at 1:100,000 have been preserved. Figure 4 shows a sample from the published map covering roughly the same area as the Bracknell study area used in our pilot analysis of the Stamp maps.

Figure 4: Second Survey 'Scapes and Fringes' map



Access and copyright: Copies of published Second Survey maps are available in various libraries, and we were given some surplus copies by King's College. All the unpublished material assembled by the Survey is now held by Professor Coleman in a second house adjoining her own in Dulwich, south London (see Appendix A). Published 1:25,000 maps are available for £4 per sheet, and unpublished 1:10,000 maps may be consulted for a fee. The 'Scapes and Fringes' sheets are available as a pack, including a 98-page book detailing the method of classification, for £30 and a copy was bought for this study.

Professor Coleman is unquestionably the principal author of the Second Survey maps, and very much alive. She is clearly disappointed by the lack of official support for her work, has invested a substantial amount of personal funds in the project, and would expect significant payment for any computerisation project. This in itself means that any immediate project should clearly focus on the Stamp Survey. She expects that in the future the material gathered by the Second Survey will be looked after by her family.

1970s re-mapping: The Second Survey re-mapped Buckinghamshire, Merseyside and Surrey, and isolated other sheets, in the 1970s. Field maps are available in Dulwich.

1.6 The 'Land Use UK' Survey, 1996-7

A third survey was conducted by the Geographical Association in the 1990s, under the leadership of Dr. Rex Walford of Cambridge University as National Secretary. The survey work was carried out by school pupils working to a detailed brief in a specially published survey handbook. However, unlike the earlier surveys and with the exception of one specific region, the data was collected by using a stratified sample of 1000 1 km square units, so no overall map of the country was produced. Nevertheless, this might provide an interesting benchmark, using essentially the methodology of the Stamp and Second surveys to gather data for a period when satellite imagery is also available. The results of the survey are reported in detail in Walford (ed.), 1997. Dr. Walford has advised us that the data sets are kept in an archive at the Geographical Association's offices in Sheffield.

2: Digitising and Disseminating the LUS maps

The aim of this section is to discuss various issues surrounding the scanning and processing of the Land Utilisation Survey maps in order to create a raster-based product suitable for viewing and disseminating in a digital format.

2.1 Image scanning

2.1.1 Resolution: Within the libraries and archiving sector, it is generally agreed that when scanning material, in order to convert an important collection into digital form, the material should be captured at a resolution of at least 300 dots per inch and at a colour depth of 8 bits per channel (24 bit colour).

Any increase of resolution above 300 dpi is usually determined by the storage capacity available to the project, the physical size of the material, and the printing and dissemination techniques applied to the subsequent imagery. There is also a threshold to resolution where any further increase will not yield a noticeable improvement in quality.

Given the level of detail and physical size of the map sheets of the Land Utilisation Survey (LUS) it was decided that the maps should be scanned at 400 dpi, 24 bit colour. Two test areas, from sheets 114 and 133, were scanned at this resolution and saved in Tagged Image File Format (TIFF or .tif).

2.1.2 Working resolution: Although 400 dpi, 24 bit colour is required for archive purposes, this resolution is not required for the imagery that is processed to extract the land utilisation categories. For this purpose the images are reduced to 200 dpi, 8 bit colour.

2.1.3 Storage: At 400 dpi, 24 bit colour, each image is approximately 310 Mb uncompressed, meaning that the total storage requirement for the raw scanned material for England and Wales is 45.3 Gb. Note that a considerable amount of further space will be required in order to store the lower resolution copies and also versions for dissemination. Projects often use DVDs to store the original scanned material. A single DVD can typically store 4.7 Gb or approximately 15 maps.

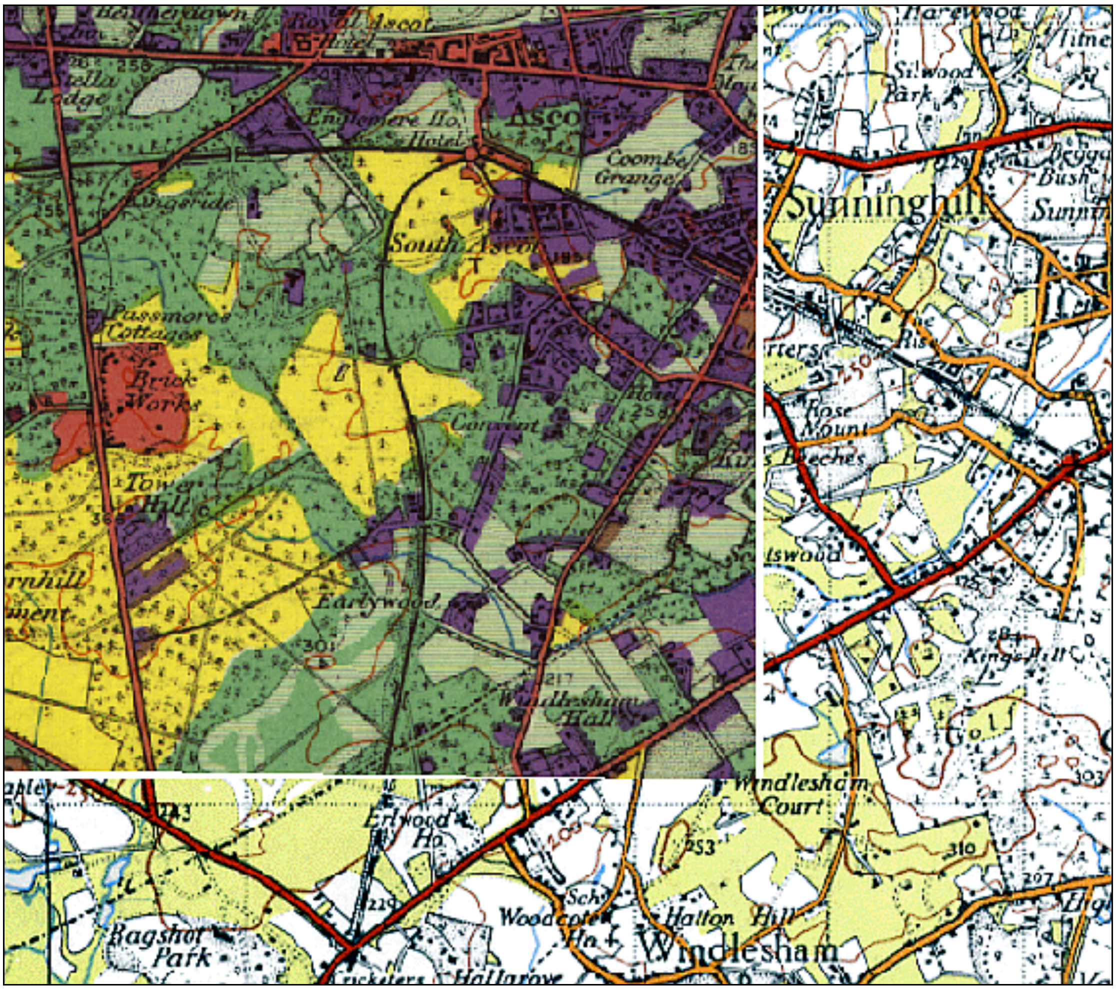
Each 200 dpi, 8 bit colour, image is approximately 26 Mb in size.

2.1.4 Scanning: For the purposes of this pilot study the two test sheets were digitised using a sheet-feed scanner. These are quick to use but have the disadvantage of not being appropriate if the original material is considered to be very delicate as the maps are fed through the scanner using rollers. An alternative is to use a high-end digital camera, mounted on a frame with an accompanying flat bed for the map, and overhead lighting system for illumination of the material. Although considered suitable for use with delicate collections, it is slower and also difficult to achieve a constant illumination across the maps. NB at least one university map library seems willing to scan their copies of the maps using a sheet-feed scanner.

2.2 Geo-referencing

The digital files of the scanned maps do not contain any information as to where the area represented on the map is located on the ground. This means that it is not possible to view, query or analyse the data with other geographic data, or indeed with any other of the scanned maps.

Figure 5: Part of a geo-referenced LUS map overlaid on a New Popular Edition map. The latter has been used to geo-reference the former



In order to create this functionality it is necessary to align, or geo-reference, the image to a map coordinate system, in this case the GB National Grid. Maps containing a printed grid are simple to geo-reference as it is possible to click on an intersection of the grid and type in the coordinates for that point. However, the LUS maps have no grid and therefore prominent landmarks must be used whose coordinates one could go out and survey or that can be identified on another, already geo-referenced, source. Using the latter approach it is possible to geo-reference a map by clicking on four or more landmarks within the LUS image, such as churches or road junctions, and then click on the same four features within an already geo-referenced map such as those that can be obtained from the Ordnance Survey.

One large disadvantage of using a product from the Ordnance Survey to geo-reference the LUS images is that the resulting combination of information would probably be regarded by the OS as a 'derived work' in which they held a copyright, and could control dissemination. Fortunately, the GBH GIS project have already created a complete set of geo-referenced 1"-to-the-mile maps that contain grid lines but were published more than fifty years ago, and are therefore free from OS copyright. These New Popular Edition maps from the 1940s have therefore been used as the source of coordinate information for geo-referencing the two test areas used in this pilot study, and could potentially be used to geo-reference all of the LUS maps.

2.3: Dissemination

If the aim of dissemination is to make the resultant imagery as widely available as possible then any solution should involve serving the maps on the Internet. There are two main methods of presenting this material, either as individual sheets or through a Map Server.

2.3.1 Individual sheets. This usually involves converting the image into a format that both compress the image well while allowing the user to zoom and pan around very rapidly. Products that create this functionality include Zoomify and MrSid. The main benefit of this method is it is quick to produce the imagery and navigation is simple. However, the images can only be displayed individually thereby losing any of the benefits associated with geo-referencing and integrating geographic data.

Examples:

http://www.collectbritain.co.uk/collections/osd/
http://www.thebanmappingproject.com/database/image.asp?ID=14892

2.3.2 Map Server. This is a piece of software designed to deliver maps and other GIS content to the Internet along with tools which allow the user to query maps and alter the display of the data. It also has the added advantage, due to Open GIS Consortium standards, of being able to receive requests from other websites and serve the relevant portion of map for display and integration with their geographic data and vice versa.

In order to serve the LUS maps in this way, it is necessary to crop the maps to remove the legend, title and anything else outside the bounding box of the map itself. The maps are then cut up into smaller tiles to speed up delivery to the Internet. Because each tile is geo-referenced and superfluous parts of each map have been removed, we can deliver what appears to be a single seamless LUS map. Furthermore, additional layers can be displayed on top of these maps, such as a vector coverage containing the land-utilisation polygons created in section 4 of this study or the 10 mile to the inch maps mentioned in section 1.

Examples:

http://mapserver.lmic.state.mn.us/landuse

http://www.dnr.state.mn.us/maps/tomo.html

http://www.search.staffspasttrack.org.uk/engine/GIS/default.asp?reset=1

3: Extraction of Land-use information: Issues

3.1 Introduction

One large advantage of scanning and geo-referencing the maps is that it is then possible to automatically extract land-use information. By detecting and homogenising areas of colour within the map into discreet classes, it is possible to produce an image that is free from clutter, and directly comparable with the same information extracted from every other map. Furthermore, by joining the sheets together and converting the data from raster to vector data it is possible to create a map of polygons for the whole study area from which can be derived land use statistics and comparisons with other geographic data sets.

Unfortunately, due to the nature of the maps, automatic extraction of these classes is difficult. It was decided, therefore, to try different approaches in order to compare the results and time taken using each technique. Figure 6 shows the three approaches for extracting land-use classes and the layout of the reporting presented in the remainder of this section of the pilot study.

Figure 6: The three approaches to extracting land-use classes from the scanned maps

Selection of trial areas
↓
Preparation of maps for processing
↙ ↓ ↘

Trial 1:	**Trial 2:**	**Trial 3:**
Class reduction method	Supervised classification	Manual digitising

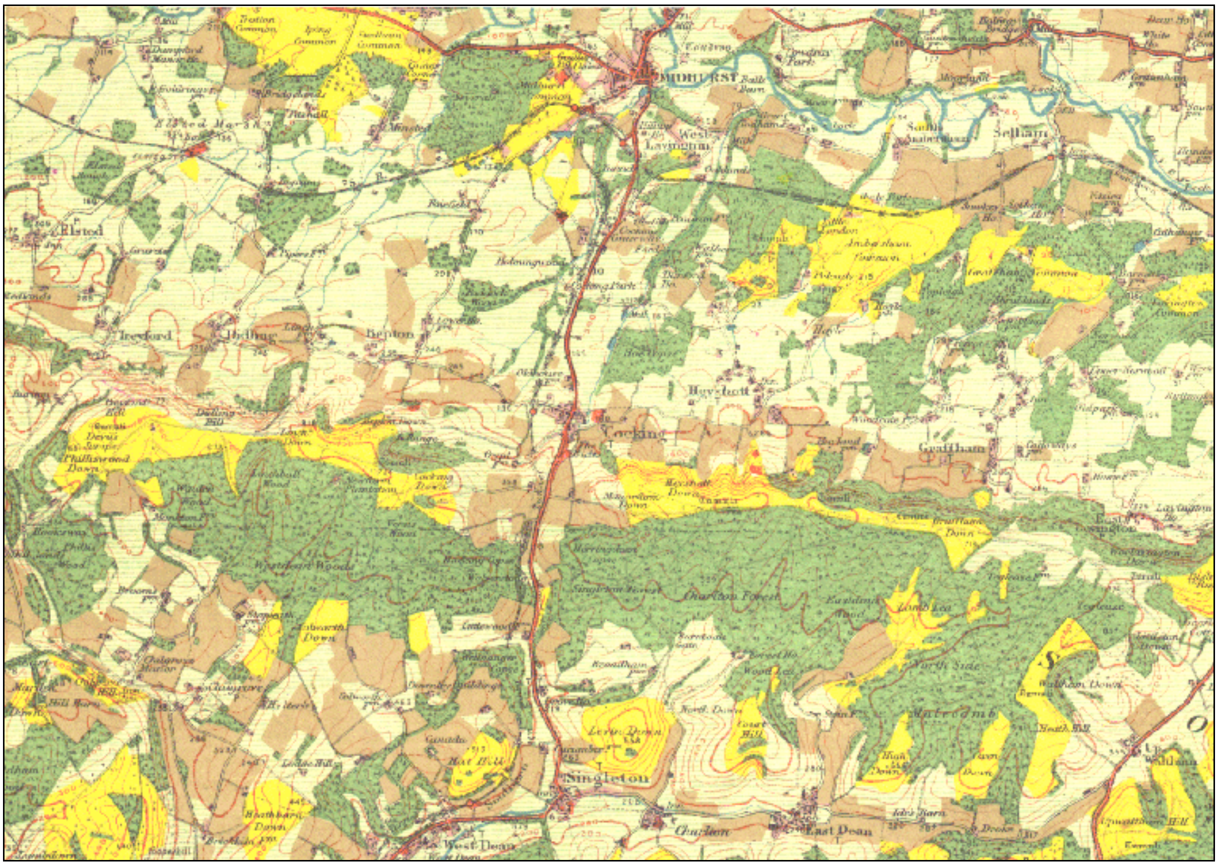
↘ ↙
Interactive editing
↘ ↙
Results, task duration and comparison
↓
Recommendations

3.2 Selection of trial areas

For the purpose of this project we have used two source maps of different quality, from the Portsmouth University collection; these are sheet 133, ‘Chichester and Worthing’ and sheet 114, ‘Windsor’. Trial sites have been extracted out from these map sheets. These two trial sites were chosen because they represent different types of landscapes. The complete trial sites are shown in figures 7 and 8. The sheet 114 site is near Bracknell and contains many built up areas and a significant network of roads. The sheet 133 site is centred on the South Downs, north of Chichester and contains more open land and has good examples of the various forest and heath classes.

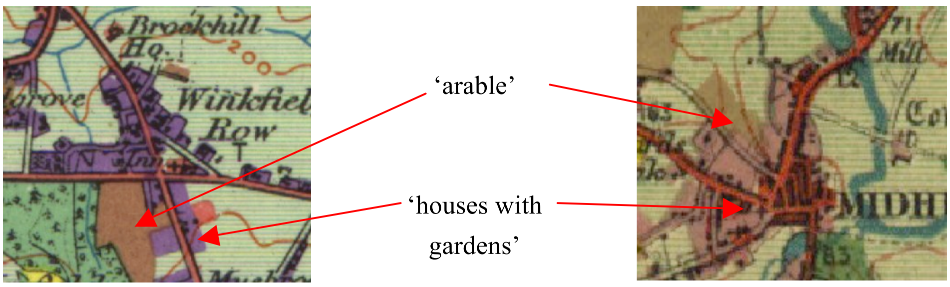
Figure 7: The Bracknell trial area source scan

Figure 8: The Chichester trial area source scan.
The image displayed here has been 'brightened for the purpose of this report



The two source paper maps have some differences in printing quality, for instance, the classes under 'gardens etc', which includes most suburban areas are a bold purple on sheet 114 but are a pale orange on sheet 133. The correct colour is the purple, however, it is known that this colour often bleaches out from these old maps. The CEH Monks Wood copies of sheet 133 shows a similar bleaching of the purple printed colour. This does not occur consistently across the map series. Other colours on sheet 133 have been affected by this apparent bleaching out of the printing ink. The strong brown representing arable land on sheet 114 is a paler brown in sheet 133. Figure 9 illustrates this situation.

Figure 9. 'Bleaching' of printed map colours, houses with gardens should be purple in sheet 133



Sheet 114 (Windsor)

Sheet 133 (Chichester)

It is expected that the differences in colour quality of the maps will affect subsequent processing. For example, it is unlikely that classification techniques applied to one trial area will work in precisely the same way when applied to the other area. For this reason it is not expected that any classification process will be able to become completely automated.

Paper documents are subject to distortion, especially over long time periods. It is necessary for the digital maps to be created in the 'correct geographical space'. This can be done using standard geo-referencing functions within various software, such as ERDAS Imagine or ESRI's various GIS systems. For these trials geo-referencing of the images was undertaken using those methods described in section 2 above.

3.3 Preparation of map scans for onward processing

The two maps sheets were scanned by Portsmouth University using methods described in section 2.1 above. Although sheet 133 was quite pale in colour compared to sheet 114, the detail retained in the scan was relatively sharp. In sheet 114 there was an apparent blurring of the edge of map detail. This is probably a direct result of the quality of the printed maps. CEH did a quick trial on sheet 114 and it was possible to apply some simple photographic sharpening, using Paintshop Pro software, see figure 10.

Figure 10. The effect of applying a sharpening function to the source scan.
These images have been enlarged here to about 4 times the source map scale

Source scan

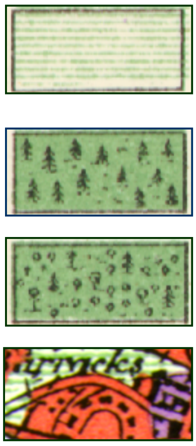
After 'sharpening'

Although potentially useful for producing a more visually pleasing facsimile of the source map, this technique does introduce a less controllable stage to the process. In this study the 'sharpened data' was not used for the subsequent stages of image processing as the 'blurring' in sheet 114 was removed as part of this latter process anyway.

The maps were scanned at a resolution of 400 dots per inch, equating to each pixel representing about 4.7 metres on the ground. This is smaller than necessary for the subsequent production of a digital map of land use classes that retains the essential original detail. In subsequent analysis it was decided to adopt a standard pixel width of 10 metres on the ground, the equivalent of scanning the maps at approximately 200 dpi.

The source maps contain topographic map information from Ordnance Survey base maps, as well as information on land use. The primary aim of this project was to capture the land use information only. To do this it is necessary to remove the remaining map detail. The main land use classes are depicted in the source maps with a series of colours combined with various map symbols. Figure 11 shows some examples of these.

Figure 11. Extracts from the map legend of a source map, and a small urban map example



These type of cartographic depictions pose some of the major technical problems; for instance, how are roads removed, and their red infill, whilst retaining the same red that is used for defining some of the urban areas (called land 'agriculturally unproductive' in the source maps)?

4: Extraction of Land Use Classes: Alternative Methodologies

4.1: Method 1: Class Reduction method

Synopsis: Classify the image into many (eg 100) colours and then reduce this down to the number of land use classes you require (targets) by visually assigning each of the 100 classes to one of the targets.

Method:

- Reduce number of colours in raster data to 100.
- Analyse all colours and assign them to a target land use class or 'other' class.
- Import basic raster data to a Geographical Information System for further refinement.
- Remove initial unwanted information such as black topographic detail.
- Convert to vector map and do further 'tidying up', such as the removal of remaining unwanted detail.

Creating discrete colour classes (target land use classes):

Early investigations (Brown, 2000) reduced the number of colours present in the initial map scans to about 50 colours. For the current trial it was decided to increase this to 100 colours, from the source scan's many thousands of colours. This then becomes a manageable number. Subsequent results suggest this is sufficient to successfully separate out the main map classes.

After much discussion between the project team members it was decided to extract the land use classes listed in Table 1. Some additional investigation has been made into the possibility of, and practical limitations of, trying to further subdivide some of these classes. This requires significant interactive intervention and analyses of the final data, and should probably be omitted due to the effort required.

Table 1: Target land use classes to capture from the source maps	
Initial map class	**Comment**
Black topological detail and text	Black - To be removed
Forest and woodland	Green with black symbols - combined from 3 subclasses
Meadowland and permanent grass	Light green (hatched line symbol)
Arable land	Brown
Open water areas	Blue, white in some cases
Rivers	Blue, linear, to be removed
Heath and moorland	Yellow, possible interactive split into 2 subclasses
Land agriculturally unproductive (e.g. Urban core)	Red, possible interactive split into 2 subclasses
Gardens etc (e.g. suburban)	Purple, possible interactive split to extract orchards

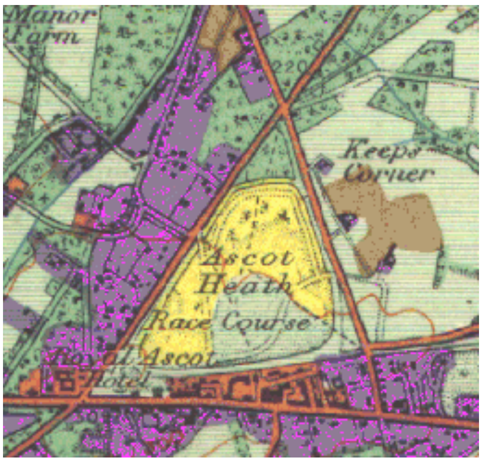
Allocating colours to target classes:

With the target classes in table 1 in mind the first step was to analyse each of the 100 colours we created in the previous step. This procedure can be done in different software packages; we have done this both in Paintshop Pro, for the Bracknell trial site, and in the ArcView GIS for the Chichester trial site. The procedure is much the same in either package:

- Select a specific colour class,
- Display it in a bright colour to contrast with the rest of the source map,
- Decide on which target class it most clearly represents.

In many cases this class allocation is easy. In some cases a class may represent black detail, and therefore needs to be identified for later dissolving out of the map. Sometimes a class is shown as very rare isolated pixels, these can be dissolved away. Sometimes the choice is not so simple, for instance, a light brown colour may appear frequently in the Arable areas, in the edges of red roads as they blur into the black road casing and in contour lines.

Figure 12: Allocation of one of the 100 colour classes to a target land use class



The bright pink pixels shown here clearly occur within the purple areas

Once this analysis is complete the data is converted into an ARC raster grid file. The 100 classes are then reclassified into their target classes (including the unwanted black pixels). The output is examined in relation to the source scan. Problem target classes are identified, the source colour(s) causing the problem are identified and the allocation of classes adjusted. This procedure is repeated until a good map representation of each target class is achieved, see figure 13 below.

Figure 13: First class allocation results, showing the black detail that needs removing

first GIS class allocation — source scan

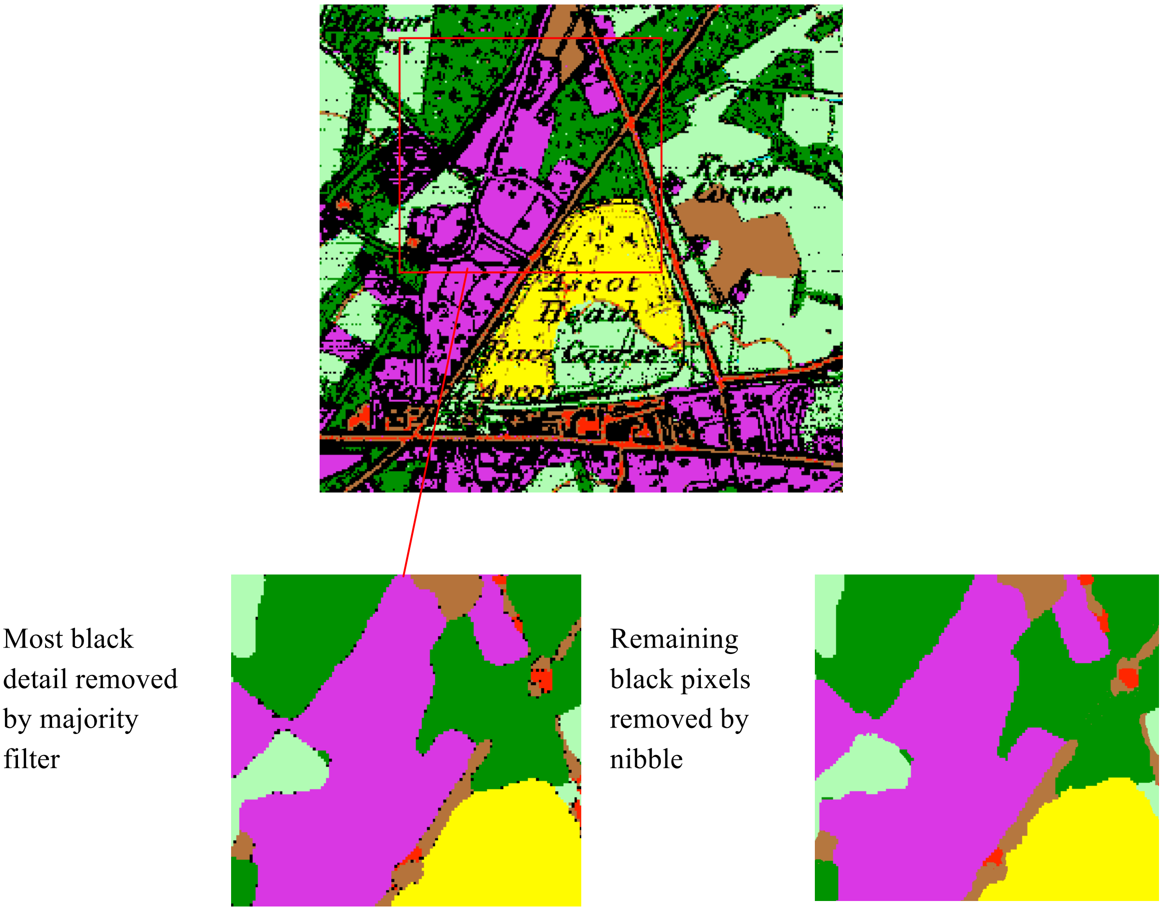
Removal of background detail

It can be seen in the first classification example shown above that, although the basic class structure appears to be correct, there are some problems. As expected there is lots of black detail: this will be easily dissolved away in the next step. There are also some other problems such as the remaining contour lines etc. Many of these features will also be removed during either the dissolving process or in the later removal of small parcels. Some will need final interactive removal.

The removal of the unwanted black detail has been done as follows:

- Use ARCGrid ‘focalmajority’ function with parameters: circle, 5, data. This successfully removes most linear features, such as road casings, and narrow text (with some remnants, especially where black was thick, such as on building symbols and larger text).
- Prepare files required for ‘nibble’ function. Make copy of output with black called ‘nodata’, and a second version where the remaining black pixels retain their original attribute. These two files are used in tandem during the subsequent ‘nibble’ process.
- Use ARCGrid ‘nibble’ function. This allows all other classes to eat into the black’ nodata’ areas, completely removing them, see figure 14 below.

Figure 14: Removal of black detail using GIS filter and nibble functions



Methodologies for interactive editing: Removal of anomalies

The most time consuming part of these procedures occurs when interactive analysis is necessary, therefore this methodology has tried to reduce this where possible. The state of the data at this stage is such that it requires the removal of a number remaining ‘anomalies’. Essentially there are two types of anomaly to be examined. There are small, unwanted parcels, remaining in the data that have not been removed by the previous processes. There also remain some data that have adopted the incorrect code: primarily these are road parcels that have remained because they are red on the original maps. They have survived because they are currently being confused mainly with red areas of unproductive land, which is a target class. In the first trial site, from sheet 114, some automatic removal has been done and some interactive removal, or recoding of attributes. Alternatives have been tried during the subsequent processing of the sheet 133 trial site. In both cases these processes were done on a vector version of the maps. These were produced using a standard raster to vector conversion process within the ARCView GIS.

Removal of erroneous small parcels

The vector versions of the maps were examined in detail in relation to the original paper map information. The smallest individual parcels that were depicted on these original maps were examined, see figure 15. The smallest features depicted on the source maps are just over a quarter of a hectare in size. A threshold of 0.28 hectares was chosen, below which features have been dissolved into the background, using the ‘eliminate’ function of the GIS. This function dissolves parcels away, and replaces them with the attribute possessed by the adjoining parcel with the longest shared boundary line, see figure 16. This works well for the majority of cases. In some instances, especially in relation to road detail, it is necessary to interactively, select an alternative adjoining value, in order to retain the cartographic integrity of the source map detail. The majority are unwanted small parcels derive from the remnants of black text etc. Figure 17 illustrates this.

Figure 15: The smallest parcels shown on the source maps

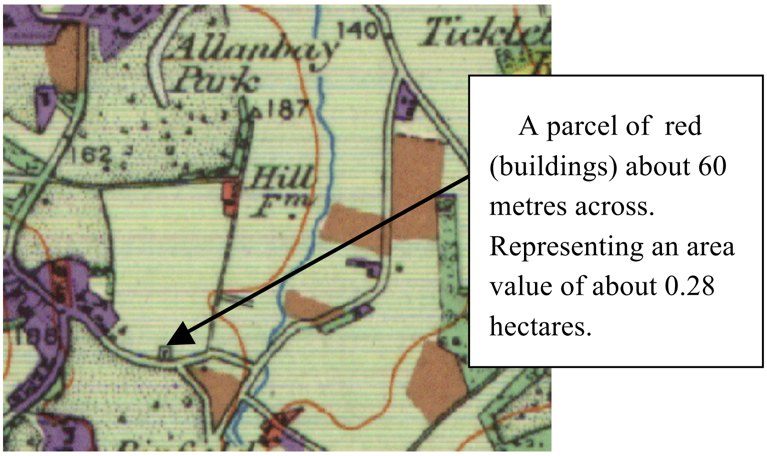
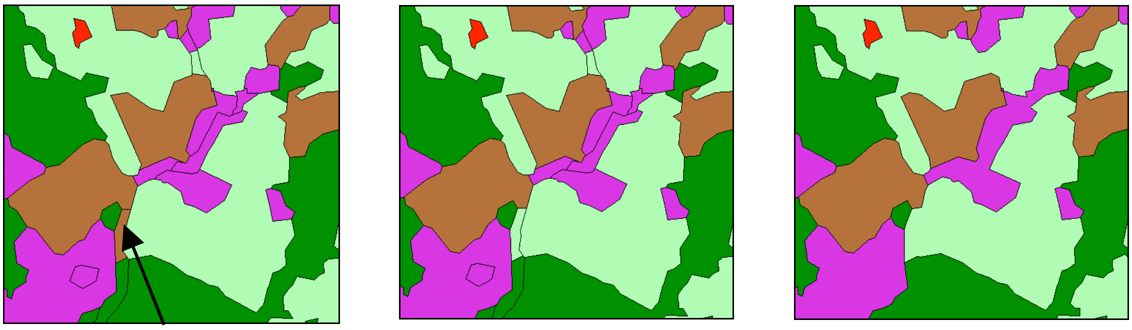
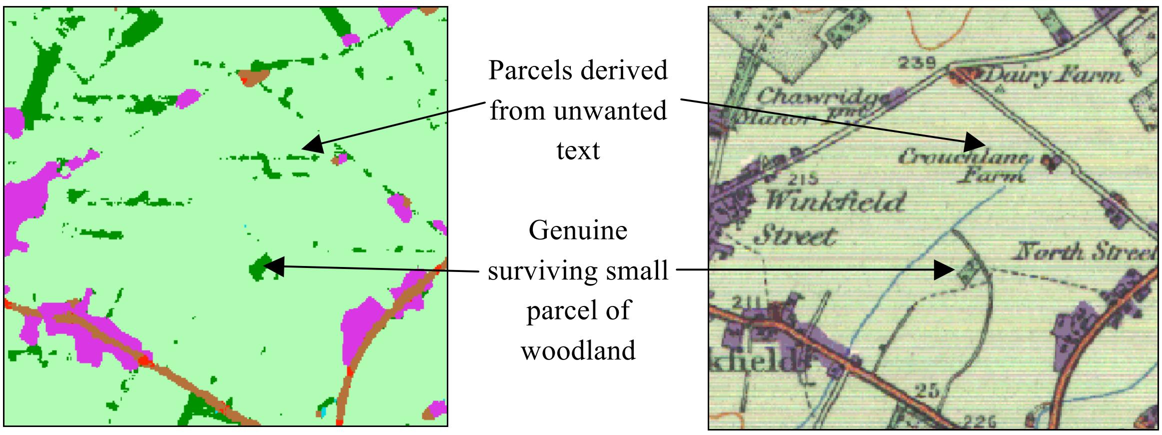


Figure 16: Ensuring the correct attribute is adopted within the area of a parcel to be eliminated



Parcel given an arable attribute | Parcel given a grassland attribute | Boundary dissolved

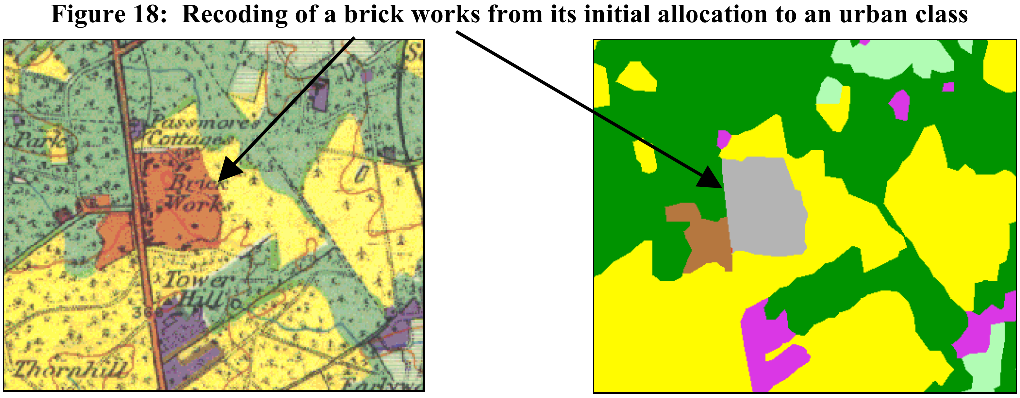
Figure 17: Some unwanted small parcels to be dissolved away automatically where possible



Other edits:

A final interactive check is necessary to ensure correct conversion from the source paper map to the final digital vector map has been achieved. During this procedure it is possible to re-examine some of our target classes. For instance, in the Bracknell site, there is one area, currently holding the red 'land agriculturally unproductive' attribute. The source map text shows that this is a brick works rather than an area of urban, see figure 18. This can be given the alternative attribute. This would be a necessary step for all such parcels, if it is decided to differentiate between these two types of cover.

Figure 18: Recoding of a brick works from its initial allocation to an urban class



4.2: Method 2:Supervised Classification

Synopsis: Identify some examples of each target class by selecting areas on screen from the image. The software then assigns every pixel in the image to one of those classes identified.

This approach is taken from standard methodologies used for classifying remotely sensed imagery such as that gathered using the SPOT and LANDSAT satellites. Although the LUS maps contain a far greater amount of 'clutter' (such as text and contours for example) than satellite images, it was considered that there would still be merit in experimenting with remote sensing classification techniques. The software used in this trial is called Erdas Imagine.

The method of classifying the image in this trial differs from trial 1 in that rather than reducing the number of classes from 256 (8 bit colour) to 100, and then further reducing these to the final seven target classes, this method tries to sort pixels into the target classes in one step. The advantage of this method is that it should be quicker as it cuts out the manual process of viewing each of the 100 classes in turn and assigning them to one of the target classes. However, the trade off is that there is less control over the process and therefore the results must be compared carefully in order to validate the technique.

Method:

- Principal Components Analysis
- Choose 'training areas' and run supervised classification
- Import raster data to a Geographical Information System for further refinement
- Remove initial unwanted information
- Convert to vector map and do further 'tidying up', such as the removal of remaining unwanted detail.

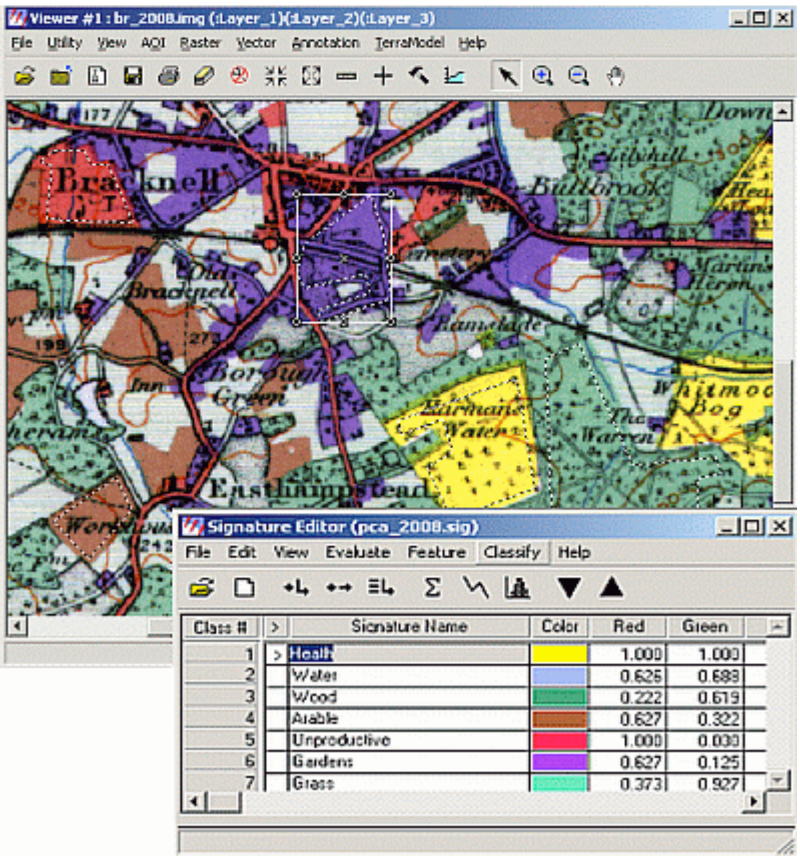
Principal Components Analysis

Principal components analysis (PCA) is a form of data compression whereby the dimentionality of the data is reduced and redundant data is compacted into fewer bands. Although it can be used on its own as a form of image enhancement, in this case it is being used to prepare the image for classification. The bands produced by PCA are non-correlated and independent, meaning that the image should subsequently be more interpretable when using the classification techniques described below.

Supervised classification

Supervised classification works like all classification techniques, by sorting the pixels of the input image into a finite number of classes based upon the value of that pixel or group of pixels. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria. However, the supervised methodology offers some subtlety as it allows the user to train the software to recognise patterns within the data and define the criteria by which these are recognised. In practice, this means digitising around some examples of 'typical' areas of each land-use (target) class in the sample LUS map. The result of this training is a set of signatures that form the criteria for the target classes.

Figure 19: Typical training areas are chosen and digitised



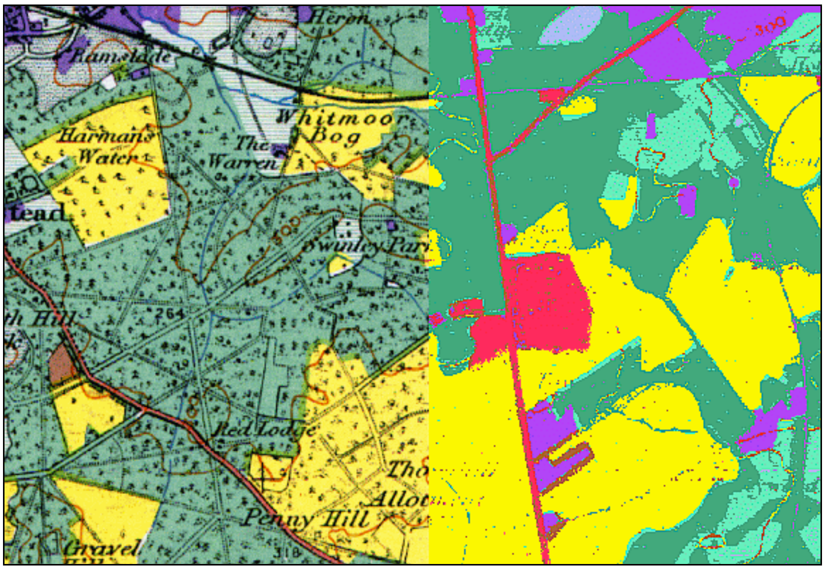
There were three reasons for trying this technique:

- It is quick to carry out
- There is the potential to train the software to ignore a lot of the unwanted clutter (such as the text)

- There is the possibility of re-using the signatures for all of the maps within the collection

Figure 19 shows a typical area identified for training purposes. Note that rather than identifying a very clean area of colour, ‘cluttered’ areas were selected in the hope that the software would learn to ignore the clutter during the classification process, thereby reducing the time spent cleaning up the data afterwards. Figure 20 shows a section of the initial results from this supervised classification.

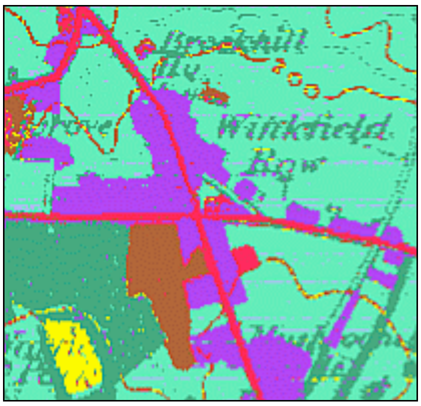
Figure 20: Initial results of the supervised classification compared with an adjacent portion of the original resource



Further processing

Although this technique looks reasonably successful in ignoring much of the features in black, it was still necessary to undertake further cleaning of the resultant image in order to create clean land use polygons. It was very noticeable that the land use types represented by more intense colours classified with more success than others. Figure 21 illustrates this, showing that the light green areas of ‘meadowland and permanent grass’ (represented by striped green shading on the original map) have not classified as well as the others, leaving a lot of clutter to try and remove.

Figure 21: Text and contours can remain visible within areas of ‘meadowland and permanent grass’



Various GIS-based techniques were employed to filter out the remaining clutter and after different trials it was concluded that the best tools were those used in the latter stages of trial 1.

These included a majority filter and eliminate functions. For a more detailed explanation of these process, please refer back to section 4.1.

Re-using the signature file

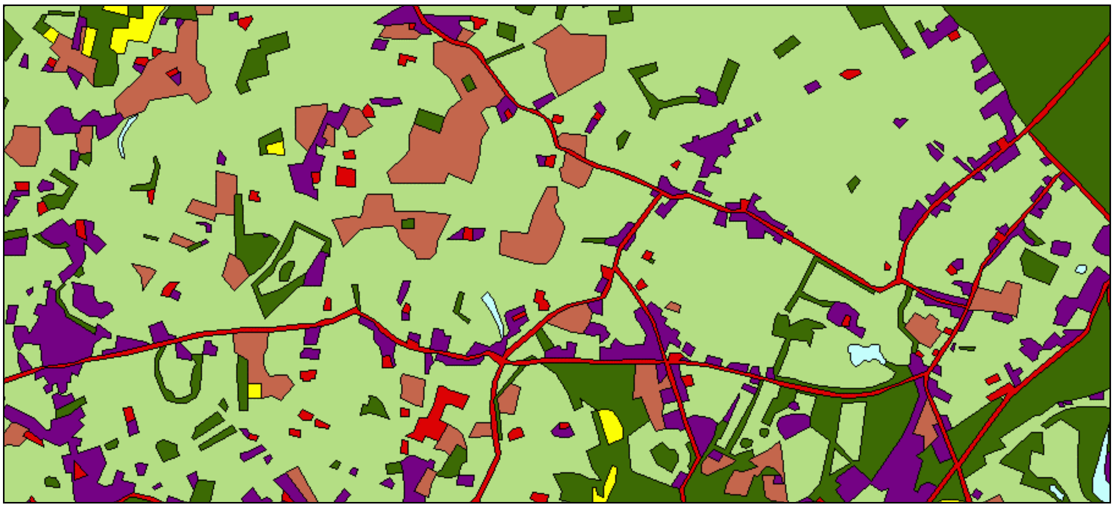
One large potential advantage to using supervised classification is that the signature file, created as a result of digitising training polygons, could be re-used to process every other map in the collection. This would man that the classification of each map could be carried out automatically, with no user input other than that required to process the first map. Unfortunately, due to the differences in hue between the same land use classes within the two test areas (see figure ?), the re-use of the signature file failed dramatically, yielding a poor classification of the test area from map 133. However, with further investigation into maps that are in a more similar condition it may be found that, in some cases, signature files can be re-used.

4.3: Method 3: Manual Digitising

Synopsis: Manually tracing around the edges of each area of land use and then assigning the correct land-use attribute to the resultant polygons.

Due to the amount of time taken to carry out the image processing described in trials 1 and 2, it was considered that a viable alternative method may be to digitise land-use classes by hand. This method has advantages over the other trials as it yields highly accurate results as well as requiring no further editing, other than edge-matching sheets together. Further advantages include being able to calculate how long it would take to digitise the whole country as well as enabling the comparison of these results with those produced by trials 1 and 2.

Figure 22: The result of manually digitising a sample of sheet 114 (Bracknell area)



The northern half of the trial area from sheet 114 was chosen as the area to be digitised manually as it was considered too time consuming to attempt to digitise an entire trial area using this method. The sample area of map was displayed inside a GIS package (ArcInfo) and then on-screen digitising carried out in order to create a new GIS coverage of polygons. Once completed, those polygons belonging to each land-use class were selected and then that class name was added as an attribute of those polygons.

Although time consuming, this trial proved successful in achieving an accurate vector representation of the sample area, as well as avoiding the lengthy editing procedures carried out using the other two methods. The results can be seen in Figure 22.

Further considerations: Edge matching

Once processed, the vector maps can be stored and used individually, or joined to create a single, seamless coverage for the whole country. In either case it may be desirable to edit the polygons at the edges of individual map sheets in order to obtain a better match when joining or displaying them. Mismatches can be caused by the printing of the original maps, geo-registration of the scanned maps, slight differences in the application of the classification techniques, or inconsistencies in classification during the original survey.

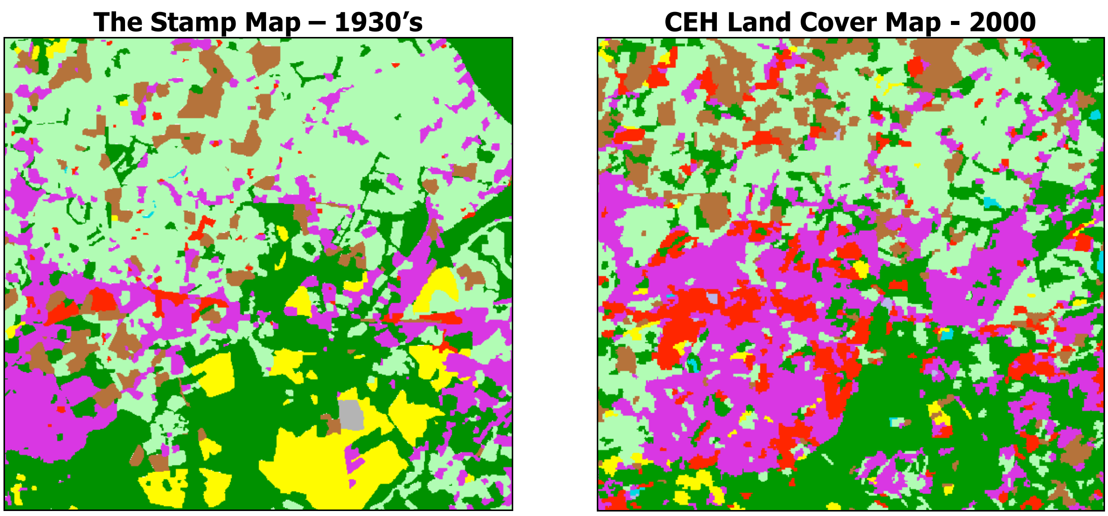
Figure 23: Before and after edgematching and dissolving shared boundaries

If a single coverage is required it will be necessary to dissolve boundaries that divide polygons of the same land-use. Note that edge matching is a time-consuming task and it is recommended that further trials be conducted to weigh up its necessity against how well the edges of the sheets match after processing.

Analytic usage

This study has not looked at the comparison of the final maps with modern land cover data held in the CEH land cover maps in any great detail. This area of investigation would be a primary goal of the planned Phase II. Some initial ideas were reported on in Brown (2000). Figure 24 illustrates a visual comparison for part of the Bracknell trial site.

Figure 24: A preliminary comparison of the 1930's with the LCM2000 map for the Bracknell trial area. The LCM2000 map has had its classes coloured up in approximate Stamp colours



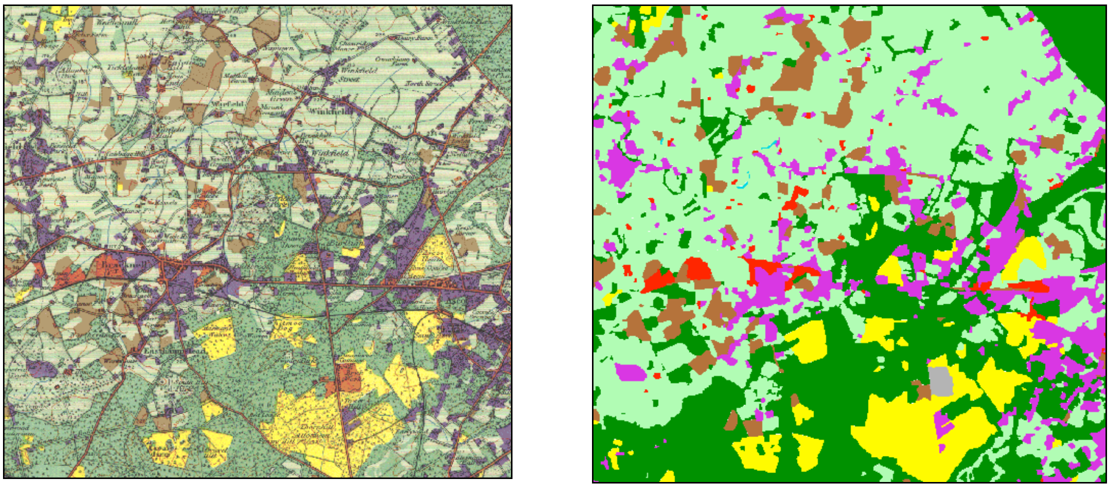
Key differences seen here include the creation of the town of Bracknell, the increase in arable land in the north, and the afforestation of heath in the south. Note these are trial images only, they may not show areas of real change.

4.4: Results

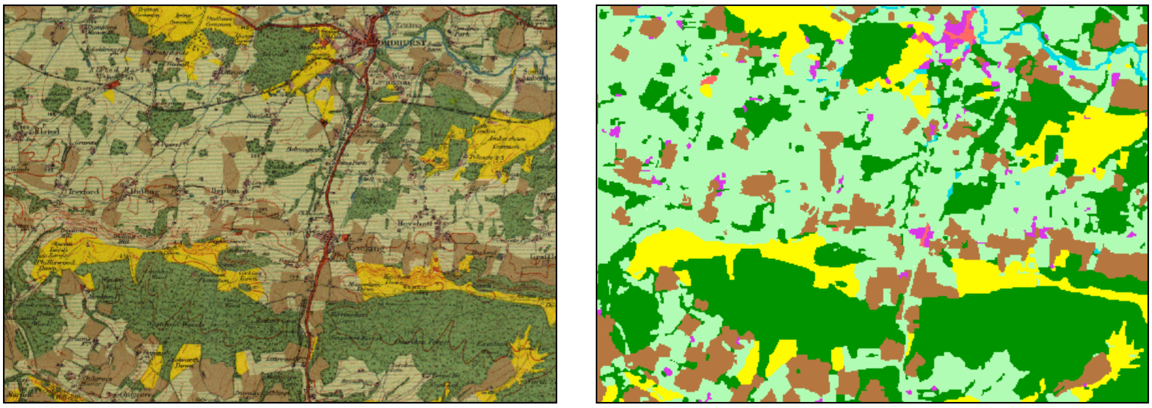
This investigation has largely concentrated on the Bracknell trial site. The Chichester trial site was used to further test and modify some of the processes, but it has not been fully completed to the same level as the Bracknell trial site. Figure 25 shows the final vector maps for the two study areas compared with the original maps.

Figure 25: Results from the two trial sites (using the methodology from trial 1)

(a) Bracknell trial site:



(b) Chichester trial site



note: this image has not been brightened,
as was done for figure 8

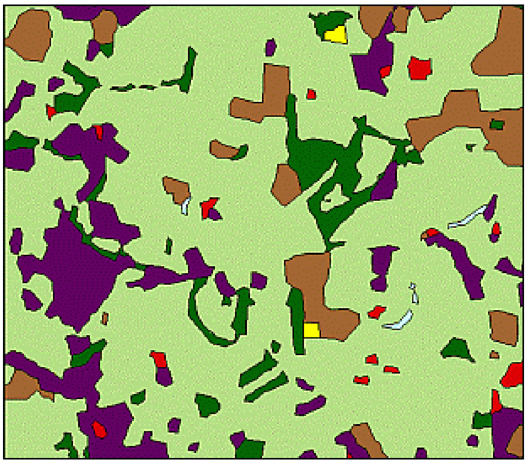
In general, the three techniques of land-use classification were all successful in extracting land use classes although each had advantages over the other methods. Trials 1 and 2 are relatively quick to carry out in comparison with manual digitising (trial 3) due to their use of semi-automated techniques of classification. 1 and 2 have produced similar results although there are differences, usually in the classification, inclusion and omission of small land parcels. The elimination of small land parcels is always bound to be a problem with automated techniques as it is difficult to distinguish these from unwanted clutter created during the classification process.

With further refinement of the techniques used in these two trials, it is expected that slightly better results can be achieved.

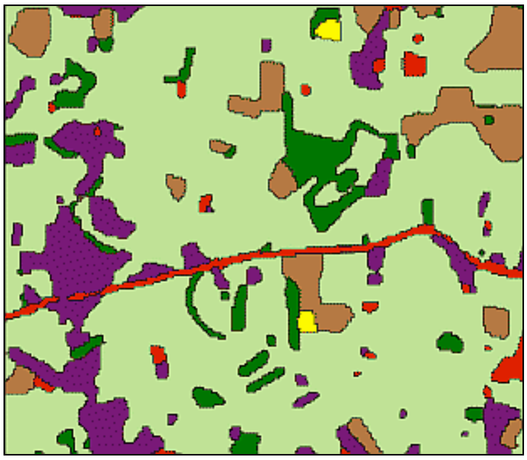
Trial 3 (manual digitising) produced very accurate results although it was very time consuming, each sheet taking nine to ten times longer to process than with the first two trials. However, one large advantage is that features that cannot be automatically detected in trials 1 and 2, such as different types of woodland, can be easily differentiated during manual digitising.

Figure 26 gives an idea of the similarity in results between the techniques used. Note that trials 1 and 2 would be even more similar had exactly the same procedures been used after classification. For example, trial 1 purposefully removed the road, whereas trial 2 tried different, less successful, filters to trial 1 in an attempt to compare different methods.

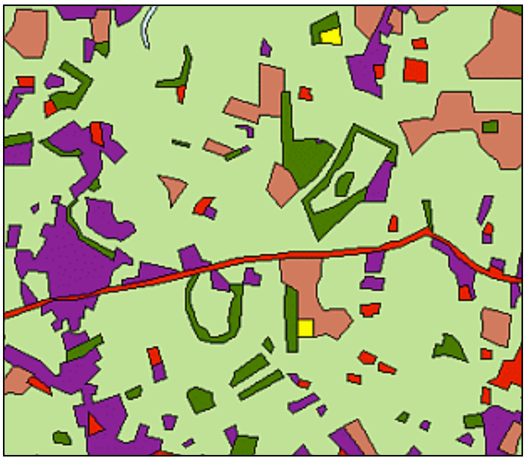
Figure 26: A comparison of a small area of map using the different techniques



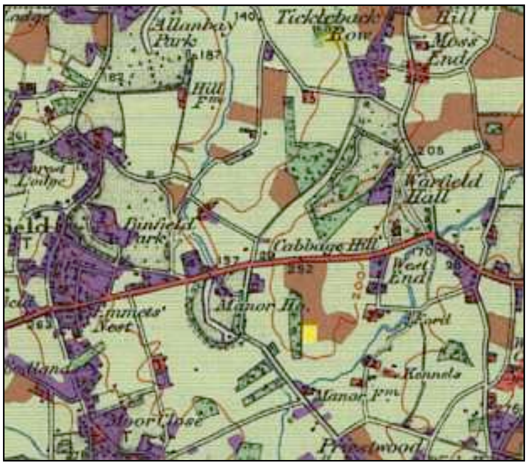
Trial 1



Trial 2



Trial 3



Original map

Unfortunately, the automatic detection of land-use classes that are differentiated by the underlying base map was not possible by any of the methods used during trials 1 and 2. Examples of these include deciduous, coniferous and mixed woodland, different types of gardens and types of heath and moorland. As these are differentiated using the black of the base map it was not possible to separate the symbols from other, unwanted black features such as text. It was possible to extract only colour, and therefore the major 'parent' classes, such as woodland, moorland, and gardens.

It should be noted that on some of the original maps the legend differentiates between the sub-classes and on some they do not. Furthermore, the details indicated by the base map may not be coincident with the survey. For example, the base map used for sheet 114 was revised in 1914, published in 1920 with minor revisions carried out in 1931. Whether these revisions included tree types, for example, is not noted. Sheet 133, printed by a different company to sheet 114, provides no dates relating to the date of the base map.

Timings

During these investigations a detailed record was kept of the time taken for each step in the process. From these figures, averages have been calculated which provide reasonable estimates of the time taken to complete an average map sheet. These times have then been extrapolated in order to cover the 146 sheets covering England and Wales.

Table 2: Estimate of time requirement

Process	Report section	Time taken per sheet (hours)	Time needed to cover England and Wales (days)
Scanning and writing to DVD	2.1	0.25	5
Geo-referencing images	2.2	0.3	6
Resampling image to alter pixel size / resolution	3.3	0.1	2
Serve on the Internet	2.3	0.7	14
Trial 1: Class reduction method	4.1	1.8	36.5
Trial 2: Supervised classification	4.2	0.7	14
Trial 3: Manual digitising	4.3	93	1898
Remove unwanted detail		7.2	146
Check and edit the final map		1.5	30.5
Total (using Trial 2)			**217.5 days**

Note that the total time required to complete all the maps in England and Wales has been calculated using trial 2 as it is a quicker process than trial 1 with each producing similar results. The processing would take 240 days using trial 1 methodology, or 1925 days by manually digitising (the last two stages do not apply to this methodology). A more detailed breakdown of time taken for the trial areas is presented in appendix C.

Although these estimates are the best that can be produced given the information collected during this pilot study, it is possible that there would be savings in time caused by familiarity with the data and repetition of the tasks. Conversely, it is also considered that the time required to carry out other processes, such as the final editing of the map, may be underestimated. Before these estimates are used as a basis for costings, an allowance for contingencies needs to be added. Similarly, most of the work could probably be done by a technician rather than the relatively senior staff who undertook this pilot project, but an allowance for supervisory time would then need to be added.

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Williamson, A., Brown, N.J., and Southall, H.R. (December 2002) ‘Digitising the Inter-War Land Use Survey of Great Britain: A Pilot project’ (Proposal for Environment Agency Funding).

Appendix A: Individuals Contacted

NB as several of the people involved with the land-use surveys are retired, some of the addresses are private and have been removed from this on-line version.

Name	Position	Address	Tel./E-mail
Beaumont, Roma	Map Librarian, Kings College, and former staff member on 2nd Survey	Department of Geography, King's College London, Strand, London WC2R 2LS	020 7848 2802 roma.beaumont@kcl.ac.uk
Board, Christopher (Dr.)	Retired from Dept. of Geography, London School of Economics; has access to surviving materials from Stamp survey	[Details on request]	[Details on request]
Cadge, Norman	Librarian, London School of Economics; responsible for surviving 6" field survey sheets	British Library of Political and Economic Science, London School of Economics, 10 Portugal Street, London WC2A 2HD	(020) 7955 7941 n.cadge@lse.ac.uk
[Details on request]	Last surviving staff member of Stamp survey; copyright holder	[Details on request]	[Details on request]
[Details on request]	Son of [copyright holder], and works in publishing; should be contacted re. copyright	[Details on request]	[Details on request]
Coleman, Alice (Prof.)	Director and copyright holder, 2nd Land Use Survey	[Details on request]	[Details on request]
Herbert, Francis	Curator of Maps, Royal Geographical Society; holds Stamp Survey materials.	Royal Geographical Society, 1 Kensington Gore, London SW7 2AR	(020) 7591 3050 F.Herbert@RGS.org
Pilfold, Will	Sussex Univ. D.Phil. student researching the life and work of Sir L. Dudley Stamp	CulCom Graduate Research Centre, Essex House, University of Sussex, Falmer, Brighton BN1 9RH	H: (01273) 516309 william@wpilfold.freeserve.co.uk
Walford, Rex (Dr.)	National Secretary to Geographical Association "Land-Use UK" project, 1996-97	Emeritus Fellow, Wolfson College, Barton Road, Cambridge CB3 9BB	[Details on request]

The assistance of other map librarians is also gratefully acknowledged: Peter Barber (British Library), Tinho da Cruz (Liverpool University), David Sherren (Portsmouth University).

Appendix B: Map Sheets published by the Stamp Survey

This checklist is taken primarily from Appendix IV of Stamp (1948), but has been re-ordered by sheet numbers in the *Popular Edition*. NB some of Stamp's maps contain parts of more than one *Popular* sheet, as indicated by the 'Oth.Sheets' column. 'Seq.' gives the sequence in which sheets were published within a particular year. Three sheets cover parts of both Scotland and England.

Nation	Pub.Yr.	Seq.	Sheet	Oth.Sheets	Area	Notes
E & W	1948-9	6	1		Lower Tweed	*Same sheet as Scotland no. 81*
E & W	1946	1	2		Holy Island	
E & W	1947	1	3		The Cheviot Hills	*Same sheet as Scotland no. 86*
E & W	1946	2	4		Alnwick & Rothbury	
E & W	1948-9	11	5		Solway Firth & River Esk	*Same sheet as Scotland no. 89*
E & W	1946	3	6		Hexham	
E & W	1936	1	7		Newcastle-upon-Tyne	
E & W	1947	8	8	pts 15 & 18	Workington & Cockermouth	
E & W	1946	4	9		Carlisle	
E & W	1946	5	10		Alston & Weardale	
E & W	1934	1	11		Durham & Sunderland	
E & W	1933	7	12		Keswick & Ambleside	
E & W	1946	6	13		Kirkby Stephen & Appleby	
E & W	1946	7	14	pt 15	Darlington & Middlesbrough	
E & W	1938	1	16		Whitby & Saltburn	
E & W	1946	8	17		Isle of Man	
E & W	1946	9	18	19	Windermere	
E & W	1947	2	20		Kirkby Lonsdale & Hawes	
E & W	1946	10	21		Ripon & Northallerton	
E & W	1938	2	22		Pickering & Thirsk	
E & W	1944	1	23		Scarborough	
E & W	1946	11	24		Lancaster & Barrow	
E & W	1946	12	25		Ribblesdale	
E & W	1945	1	26		Harrogate	
E & W	1944	2	27		York	
E & W	1940	1	28		Great Driffield & Bridlington	
E & W	1936	2	29		Preston, Southport & Blackpool	
E & W	1937	1	30		Blackburn	
E & W	1938	3	31		Leeds & Bradford	
E & W	1940	2	32		Goole & Pontefract	
E & W	1938	4	33	34	Hull	
E & W	1933	4	35		Liverpool & Birkenhead	
E & W	1936	3	36		Bolton & Manchester	
E & W	1937	2	37		Barnsley & Sheffield	
E & W	1938	5	38		Doncaster	
E & W	1938	6	39		Scunthorpe & Market Rasen	
E & W	1942	1	40	48	Grimsby & Louth	
E & W	1944	3	41		Anglesey	
E & W	1943	3	42		Llandudno & Denbigh	
E & W	1937	3	43		Chester	

Nation	Pub.Yr.	Seq.	Sheet	Oth.Sheets	Area	Notes
E & W	1935	1	44		Northwich & Macclesfield	
E & W	1939	1	45		Buxton & Matlock	
E & W	1937	4	46		The Dukeries	
E & W	1940	3	47		Lincoln	
E & W	1944	4	49		Portmadoc & Criccieth	
E & W	1944	5	50		Bala	
E & W	1943	4	51		Wrexham & Oswestry	
E & W	1938	7	52		Stoke on Trent	
E & W	1939	2	53		Derby	
E & W	1935	8	54		Nottingham	
E & W	1935	2	55		Grantham	
E & W	1937	5	56		Boston	
E & W	1935	10	57		Fakenham	
E & W	1933	3	58		Cromer	
E & W	1945	2	59	pt 68	Dolgelly & Lake Vyrnwy	
E & W	1943	1	60		Shrewsbury & Welshpool	
E & W	1938	8	61		Wolverhampton	
E & W	1937	6	62		Burton & Walsall	
E & W	1935	9	63		Leicester	
E & W	1937	7	64		Peterborough	
E & W	1937	8	65		Wisbech & Kings Lynn	
E & W	1935	3	66		Swaffham & East Dereham	
E & W	1934	3	67		Norwich & Great Yarmouth	
E & W	1945	3	69	pt 68	Llanidloes	
E & W	1942	5	70		Bishop's Castle	
E & W	1939	3	71		Kidderminster	
E & W	1934	4	72		Birmingham	
E & W	1940	4	73		Rugby	
E & W	1942	2	74		Kettering & Huntingdon	
E & W	1940	5	75		Ely	
E & W	1935	11	76		Thetford	
E & W	1937	9	77		Lowestoft & Waveney Valley	
E & W	1946	13	78		Lampeter	
E & W	1947	3	79		Llandrindod Wells & Tregaron	
E & W	1942	6	80		Kington	
E & W	1937	10	81		Worcester	
E & W	1937	11	82		Stratford on Avon	
E & W	1942	3	83		Northampton	
E & W	1937	12	84		Bedford	
E & W	1938	8	85		Cambridge	
E & W	1939	4	86		Bury St Edmunds & Sudbury	
E & W	1933	5	87		Ipswich	
E & W	1936	4	88		St. David's & Cardigan	
E & W	1947	4	89		Carmarthen	
E & W	1947	5	90		Brecon & Llandovery	
E & W	1945	4	91		Abergavenny	
E & W	1942	7	92		Gloucester & Forest of Dean	
E & W	1942	8	93		Stow on the Wold	

Nation	Pub.Yr.	Seq.	Sheet	Oth.Sheets	Area	Notes
E & W	1942	4	94		Bicester	
E & W	1934	2	95		Luton	Reprinted in 1938
E & W	1937	13	96		Hertford & Bishop's Stortford	
E & W	1939	5	97	98	Colchester & Clacton on Sea	
E & W	1935	12	99		Pembroke	
E & W	1937	14	100		Llanelly	
E & W	1936	5	101		Swansea & Aberdare	
E & W	1936	6	102		Newport	
E & W	1935	18	103		Stroud & Chepstow	
E & W	1942	9	104		Swindon & Cirencester	
E & W	1940	6	105		Oxford & Henley on Thames	
E & W	1935	13	106		Watford	
E & W	1935	14	107		N.E.London & Epping Forest	
E & W	1937	15	108		Southend & District	
E & W	1936	7	109		Pontypridd & Barry	
E & W	1939	6	110	111	Bath & Bristol	
E & W	1935	15	112		Marlborough	
E & W	1936	8	113		Reading & Newbury	
E & W	1933	1	114		Windsor	
E & W	1935	16	115		S.E.London & Sevenoaks	
E & W	1938	11	116		Chatham & Maidstone	
E & W	1936	9	117		East Kent	
E & W	1945	5	118	119	Exmoor	
E & W	1936	10	120		Bridgwater & Quantock Hills	
E & W	1940	7	121		Wells & Frome	
E & W	1939	7	122		Salisbury & Bulford	
E & W	1936	11	123		Winchester	
E & W	1938	12	124		Guildford & Horsham	
E & W	1938	13	125		Tunbridge Wells	
E & W	1939	8	126	135	Weald of Kent & Hastings	
E & W	1945	6	127		River Torridge	
E & W	1945	7	128		Tiverton	
E & W	1943	6	129	139	Chard & Axminster	
E & W	1943	5	130	131	Yeovil & Blandford	
E & W	1937	16	132		Portsmouth & Southampton	
E & W	1936	12	133		Chichester & Worthing	
E & W	1936	13	134		Brighton & Eastbourne	
E & W	1946	14	136		Boscastle & Padstow	
E & W	1942	10	137		Dartmoor, Tavistock & Launceston	
E & W	1938	14	138		Dartmoor & Exeter	
E & W	1943	2	140		Weymouth & Dorchester	
E & W	1936	14	141		Bournemouth & Swanage	
E & W	1933	2	142		Isle of Wight	
E & W	1946	15	143		Truro & St Austell	
E & W	1942	11	144		Plymouth	
E & W	1946	16	145		Torquay & Dartmouth	
E & W	1935	4	146		Land's End & Lizard	

Nation	Pub.Yr.	Seq.	Sheet	Oth.Sheets	Area	Notes
Scot	1933	6	4		South Mainland (Shetland Islands)	

Scot	1939	9	6		Orkney Islands (Mainland)	
Scot	1936	15	12		Wick	
Scot	1940	8	28		Nairn & Cromarty	
Scot	1940	9	29		Elgin & Keith	
Scot	1948-9	1	30	pt 31	Banff & Fraserburgh	Peterhead on 31
Scot	1948-9	2	40	pt 31	Inverurie & Ellon	Peterhead on 31
Scot	1935	17	45		Aberdeen	
Scot	1948-9	3	51		Stonehaven & Brechin	
Scot	1935	5	53		Sound of Mull	
Scot	1948-9	4	58		Arbroath & Montrose	
Scot	1935	6	59		Iona & Colonsay	
Scot	1935	7	60		North Jura & Firth of Lorne	
Scot			63		Perth & Strath Earn	Listed as available by David Archer, although not in Stamp's list
Scot	1948-9	5	64		Dundee & St.Andrews	
Scot	1947	6	66		Loch Lomond	
Scot	1947	7	67		Stirling & Dunfermline	
Scot	1933	8	68		Firth of Forth	
Scot	1940	10	72		Glasgow	
Scot	1940	11	73		Falkirk & Motherwell	
Scot	1936	16	74		Edinburgh	
Scot	1944	7	75		Dunbar & Lammermuir	
Scot	1937	17	78		Kilmarnock & Ayr	
Scot	1945	8	79		Lanark	
Scot	1945	9	80		Peebles & Galashiels	
Scot	*1948-9*	*6*	*81*		*Kelso/Lower Tweed*	*(Same as E & W sheet 1)*
Scot	1948-9	7	82		Ailsa Craig & Girvan	
Scot	1948-9	8	83		Loch Doon	
Scot	1944	8	84		Nithsdale & Moffat	
Scot	1945	10	85		Hawick & Eskdale	
Scot	*1947*	*1*	86		*The Cheviot Hills*	*(Same as E & W sheet 3)*
Scot	1948-9	9	87		Newton Stewart	
Scot	1948-9	10	88		Dumfries	
Scot	*1948-9*	*11*	*89*		*Solway Firth & River Esk*	*(Same as E & W sheet 5)*
Scot	1948-9	12	90		Stranraer	
Scot	1948-9	13	91		Wigtown	
Scot	1948-9	14	92		Castle Douglas & Kirkcudbright	

Appendix C: A detailed breakdown of times taken during trial 1

The times described in table C1 are an estimate of the time taken to carry out processes without the development and testing time included. Table C2 is an estimate of how long it would take to do a single whole map sheet. The Bracknell trial site is about 11km across and the final vector map contains about 600 parcels. The Chichester site (section processed to completion) is about 8km across and the final vector map contains about 650 parcels (about 100 still need editing). The main processing stages on the Chichester trial down to the 'nibble stage' was done on a full half map sheet. The vector edits were only done on the selected portion of this dataset.

Table C1: Estimates of times for each step in the process

Processing stage:	**Approximate time (hours):**		**Comment:**
	Bracknell	**Chichester**	
Select out trial area from scan	0.1	0.1	
Improve scan quality	0.2	0.3	Optional – not used
Alter pixel size	0.1	0.1	Opted for 10m on ground
Assign 100 colours to target class – first choice	1.8	1.1	Chichester was significantly quicker because the technique had already been tested
Refine choices	0.7	0.5	
Remove black detail with:			
Majority filter	0.1	0.1	
Nibble	0.2	0.2	
Vector eliminate and edit	2.0	2.3*	
Check and edit final vector map	0.5	0.3*	
TOTALS	**5.7**	**5.1**	

* based on incomplete testing

Table C2: Projected time to do one average sheet from start to finish	
Processing stage	**Estimate of time to process one Dudley Stamp Map sheet.**
Select out trial area from scan	-
Improve scan quality	0.2
Alter pixel size	0.1
Assign 100 colours to target class – first choice	1.2
Refine choices	0.6
Remove black detail with:	
Majority filter	0.1
Nibble	0.2
Vector eliminate and edit	7.5
Check and edit final vector map	1.5
TOTALS:	**11.4**

Some additional comments on timings:

- When processing a series of map sheets, all times should reduce significantly as the 'user' becomes more familiar with the processes involved.
- Some of the stages can be done on multiple map sheets, thereby reducing times.
- Whichever method, or combination of methods, is used in creating the final pre-edited vector map, a final thorough edit of the product will be essential. The estimate of 1.5 hours to do this is probably a significant underestimate.

Appendix D: Technical procedures and software used during trials

Task	**Software**	**Function**
Select out trial area from scan	Paintshop Pro / Photoshop	crop image
Improve scan quality	Paintshop Pro / Photoshop	sharpen
Alter pixel size	Paintshop Pro / Photoshop	resize
	ArcGrid	resample
Geo-register imagery	ArcInfo	Projectdefine (greatbritain grid)
		register and rectify
Classification:		
Trial 1*:* Assign 100 colours to target class	Paintshop Pro	display and 'edit pallette'
	ArcView	legend editing, reclassify
Trial 2: PCA and Supervised Classification	ERDAS IMAGINE	
Trial 3: Manual digitising	ArcEdit	
Remove unwanted detail		
Majority filter	ArcGrid	focalmajority (circle, 5, data)
Nibble	ArcGrid	nibble
Vector eliminate and edit	ArcInfo	eliminate on parcel size
	ArcView	shapefile editing of vectors & attributes
Check and edit final vector map	Arcview	shapefile editing of vectors & attributes

Appendix E: Digital data supplied on CD

Scanning and Geo-registering:

File:	Contents:
Rectifybracknell_2008.tif & tfw	Bracknell trial area, resampled from 400 dpi 24 bit colour to 200 dpi 8 bit colour, geo-registered to the National Grid using out of copyright OS New Popular Edition maps.
Rectifychichester.tif & tfw	Part of the Chichester sheet (133) geo-registered.
Newpop169.tif	Geotiff of sheet 169 of the out of copyright, geo-registered OS New Popular Edition.

Trial 1: Class reduction method and post-processing:

Bracknell datasets:

File:	Contents:
Bracknell1.tif	extracted source image
Bracknell2.tif	source image enhanced by increase of brightness
Bracknell3.tif	image reduced to 256 colours
Bracknell4.tif	pixel size increased to 8.3 metres
Bracknell5.tif	image reduces to 100 colours
Bracknell	grid – from image file via Arc 'imagegrid function (not geocorrected)
Brack4	grid – first allocation to target classes
Brack5	grid – black detail as nodata
Brack7	grid – result of focalmajority function
Nib1	grid – result of nibble function
Brack12 (x5)	shapefile components – from nib1 – approx geocorrection
Brack16 (x5)	shapefile components – small parcels eliminated
Brack17 (x5)	shapefile components – edited road parcels
Brack19 (x5)	shapefile components – final shapefile

Chichester datasets:

File:	Contents:	
Chich1	grid – extracted from source image – 256 colours	coords wrong
Chich8	grid – reduced to 100 colours – pixels size 8.1m	coords wrong
Chich9	grid – first allocation to target classes	coords wrong
Chich11	grid – improved choice	coords wrong
Chich13	grid – result of focalmajority function	coords wrong
Chich14	grid – result of nibble function	coords wrong
Chich17 (x5)	shapefile components – small parcel eliminated	coords wrong
Chich18 (x5)	shapefile components – roads part edited	coords wrong
Chich19 (x5)	shapefile components – contour edits	coords wrong
Chich20 (x5)	shapefile components – dissolved boundaries	coords wrong
Chich23 (x5)	shapefile components – final part edited parcels	correct coords!
Chich7.tif	Source image extract	

Trial 2: Supervised Classification and post processing:

Experiment 1: Supervised classification, raster filtering and then vector eliminate

File:	Contents:
Br_1008.tif	Scanned image of the Bracknell trial area resampled to 100 dpi in order to reduce the number of unwanted pixels after classification. Possibly not ideal as it coarsened the image a little too much. Not geo-registered.
Supresample.tif	The raw result of supervised classification into 7 classes
Testr50	Grid created by running a majority filter fifty times (using an AML program).
Test13	Polygon coverage after running focalmajority and eliminate functions on testr50. Although not perfect, this has had no manual editing at all.

Experiment 2: Supervised classification, eliminate and then smooth edges using raster filtering

File:	Contents:
Bracknell_2008.tif & tfw	Bracknell trial area, 200 dpi 8 bit colour. Not geo-registered.
Supervised.tif	The raw result of supervised classification into 7 classes
Hi7	Polygon coverage. This has been created by using the eliminate function, setting different criteria for different classes. Eg Area and area / perimeter ratios. Note the problem with any yellow areas touching the edge of the study area. This was caused during a 'dissolve' function but later fixed.
Hi9	Grid produced after a bit of manual editing of Hi7
Hi12	'Final' coverage produced by running two majority filters on Hi9.

Trial 3: Manual Digitising

File:	Contents:
Rectifybracknell_2008.tif & .tfw	Bracknell trial area, 200 dpi 8 bit colour, geo-registered to the National Grid using out of copyright OS New Popular Edition maps.
Mydigi	Polygon coverage (shapefile) created by manually digitising the northern half of the Bracknell study area.